GMEP Year 2 Report Summary

The Glastir Monitoring and Evaluation Programme (GMEP) provides a comprehensive programme to monitor the effects of Glastir and contribute towards providing national trend data towards a range of national and international biodiversity and environmental targets. GMEP is now in its third year of the initial four year baseline assessment period. This annual report presents results from the second year of the programme. GMEP fulfils a commitment by the Welsh Government to establish a monitoring programme concurrently with the launch of the Glastir scheme and as such is a major development from past monitoring programmes which have only reported after schemes have been closed. The project ensures compliance with the rigorous requirements of the European Commission's Common Monitoring and Evaluation Framework (CMEF) through the Rural Development Plan (RDP) for Wales. The early findings from GMEP has already provided fast feedback to Welsh Government as to how to spatially target payments to maximise benefits as the scheme progresses.

Beyond Glastir outcome reporting, GMEP data and models will also contribute to a range of other reporting requirements including the Water Framework Directive, Habitats Directive and the Greenhouse Gas Emission Inventory and actions which arise from the Environment Bill such as the State of Nature Resources report, National Natural Resources Policy and Area Statements. Central to the Environment Bill is the need to adopt a new, more integrated, approach to managing our natural resources in a more sustainable way while safeguarding and building the resilience of natural systems to continue to provide these benefits in the long term. Resilience is considered to be greater where extent, condition, connectivity and diversity are high. Many GMEP metrics can be mapped onto these requirements and thus could be exploited to map these 4 properties for different areas in the future. These benefits will underpin certain aspects of the Well-being and Future Generations Bill. Another potential use of the GMEP data is in support of work by Defra and Welsh Government in their development of National Accounts to include aspects of the natural resources (i.e. carbon, water and soil) and their combined value as whole ecosystems (i.e. forests, wetlands etc.). GMEP data can contribute to the provision of the underpinning robust and auditable data required for this activity.

GMEP will therefore improve the empirical evidence base for the current state and integrity / condition of Wales's natural assets (termed natural capital) and how these are changing in response to drivers such as climate change, land management practices and air pollution onto which Glastir options are superimposed. The challenge to the GMEP team is to isolate the changes connected to Glastir options=s itself which is the primary purpose of the monitoring and evaluation programme. Changes in the extent and integrity of the natural capital in turn impacts on how well they can deliver the ecosystem functions and services we need and value. This link is currently not well quantified. The distinction between natural capital and services is important as capital is a longer term asset which we want to protect for the future and is hard to value in itself, whereas the services which flow from this capital are what economists and social scientists are able to value and which have particular relevance for the Well-being of Future Generations Bill. This valuation step is an essential one if we are to provide a grounded framework for understanding the choices government and society face. The GMEP team is working on these issues through its work on landscape perception and use, social surveys and farmer practice surveys. However, there is a large topic which will need additional work beyond what resources are currently available within the GMEP project.

The GMEP team which is delivering this comprehensive programme compromises a mix of organisations with different specialisations covering the different schemes activities, objectives and outcomes. The programme is led by the Natural Environment Research Councils' Centre for Ecology & Hydrology (CEH), an independent public research body. CEH has a research station in Bangor

which provides the leadership and coordination of GMEP. The project consortium includes ADAS, APEM, Bangor University, Biomathematics and Statistics Scotland, Bowburn Consultanty, British Geological Survey, British Trust for Ornithology, Butterfly Conservation, ECORYS, Edwards Consultants, Staffordshire University, University of Aberdeen, University of Southampton, and Victoria University of Wellington, New Zealand.

The GMEP approach and reporting requirements

In summary, the basic approach of GMEP is a combined data and modelling programme which utilises existing data enhanced by a major new rolling field survey which provides co-located data for a range of environmental metrics. Modelling work provides methods for integrating and upscaling survey data for national scale reporting and exploring possible future scenarios of possible outcomes of the scheme. The co-located survey data allows reporting against the six intended outcomes of Glastir and the trade-offs and co-benefits of Glastir payments between these outcomes. The six outcomes are: Combating climate change; Improving water quality and managing water resources to help reduce flood risks; Protect soil resources and improve soil condition; Maintaining and enhancing biodiversity; Managing and protecting landscapes and the historic environment; and Creating new opportunities to improve access and understanding of the countryside; and Woodland creation and management. In addition to these original Glastir Outcomes, in September 2014 the Auditor General for Wales published his report[1] on Glastir. The report contained a series of observations and related recommendations including a number associated with the setting of scheme targets and monitoring actual scheme impact against scheme targets which has had an impact on the reporting requirements of the GMEP project. He identified six Strategic Objectives. To respond to these recommendations, GMEP has worked with the Welsh Government and the GMEP Advisory Group to develop a small number of impact indicators for each Glastir Strategic Objective. Metrics under consideration are:

[1] http://audit.wales/publication/glastir

Strategic Objective	Reportable Indicator
1.To increase the level of investment into measures to mitigate greenhouse gas emissions with the aim of contributing towards a reduction of net emissions from the land based sector in line with our international obligations	Contribution by land use and land use change ($ktCO_2eq\ yr^{-1}$) (excludes peat soils)
	Agriculture Emissions[6] (CO_2eq (kt N_2O + CH_4))
	Agriculture emissions including embodied emissions (typical average farm data only tCO_2eq/ha) Beef Dairy Mixed Sheep
2.To increase the level of investment into measures for climate change adaptation with the aim of building greater resilience into both farm and forest businesses and the wider Welsh economy and environment to ongoing climate change	Farmer Practice Survey to give an indication of farm business split by dairy, cattle, mixed and sheep and forestry
	Species richness / diversity of the wider countryside split by plants, birds and pollinators on arable land, improved land, habitat land and woodland
	Farmland bird indicator
	Habitat diversity
	Mean patch size (for habitat and Broadleaved woodland only)
3.To increase the level of investment into measures to manage our water resources effectively with the aim of contributing towards an improvement in water quality in Wales and to meeting our obligations under the Water Framework Directive	WFD compliant headwater stream site classification (uses a broad set of indicator of ecological condition based on macroinvertebrates, diatoms, habitat modification, nutrients) (% in high or good condition)
	Modelled area of land mitigating runoff /flood (%)[1]
4.To focus increased resources on an identified list of priority species and habitats with the aim of contributing towards a reversal in the decline of Wales's native biodiversity and to meeting our obligations under the EU Biodiversity 2020 agenda	12-15 Priority Habitat extent and condition (Only where both are reportable together)
	Priority species numbers (birds (17 of the 51 section 42 species), butterflies (6 of the 15 Section 42 butterfly species))
	Proxy habitat condition bespoked for particular needs of priority species (aggregated metric across all specie) in and out of scheme
5.To put in place measures and investment which maintain and enhance the characteristic components of the landscape and historic environment of rural Wales and to encourage increased public appreciation and access to the countryside	Landscape quality - Median Visual Quality Index (index from 0 – 1.0) in and out of scheme initially (then change over time)
	Historic Environment Feature Condition (% in 'Sound' or 'Excellent' condition)[2]
	Public Rights of Way (% open and accessible).
	Outdoor recreation use survey metric
6.To use agri-environment investment in way that encourages positive environmental outcomes but also contributes towards farm and forest business profitability and the wider sustainability of the rural economy	Farmer Practice Survey – with a question asking whether the business has benefitted from the Glastir scheme. Split by forest, dairy, cattle, sheep and mixed enterprise.
	HNV Farmland area (aggregate metric under development)

Table 01 *Impact Indicators for reporting against the six Strategic Objectives of Glastir*

Table 01 illustrates the wide range of environmental outcomes and measurements embedded within the GMEP programme of work i.e. a range of soil and water quality metrics, landscape and historic features, plant and freshwater diversity, greenhouse gas emissions, condition assessment of historic features, pollinator and four bird surveys, socio-economic surveys of benefits to the farming and forestry industries and the wider Wales community.

The GMEP cycle

As GMEP survey sites are revisited on a 4-year rolling cycle and we are currently in Year 3 of this initial 4 year cycle, the current Year 2 results contribute towards a baseline against which the future impacts of Glastir payments will be assessed. By Glastir Outcome, work focussed on biodiversity (including woodland habitats) accounts for 42% of the total GMEP budget, 41% is allocated across soils, waters, climate change mitigation, landscape and historic features, trade-offs and co-benefits, and the remaining 17% allocated to underpinning activities such as informatics, the data portal and project management. The field survey involves two parts namely the Wider Wales and Targeted components. The Wider Wales survey squares are chosen to represent the background conditions across Wales and are chosen by randomly sampling within assigned land classes. This helps GMEP to deliver the required data on national trends. Targeted squares are then chosen to specifically capture Glastir related activity.

Summary of progress

Years 1 and 2

Within Year 1, GMEP focussed on establishing the field programme and using an ensemble of models to explore potential outcomes from different scenarios of uptake of 6 Glastir options. In Year 2, we have continued with the field survey and focussed on analysis of Years 1 & 2 data together with data from other sources notably Natural resources Wales, the National Forestry Inventory, Plantlife, UK Butterfly Monitoring Scheme, the Breeding Bird Scheme and Countryside Survey. Long term trends identified are reported here (or in the data portal). We also analysed the GMEP data to identify if land coming into the scheme was different in quality to that outside, and if we could detect the legacy effects of past agri-environment schemes. The biodiversity team focussed on developing techniques for reporting on impacts for Priority species and habitats with work continuing on the development and testing of the landscape quality / perception tool. Modelling efforts were focussed on establishing the baseline data for direct and indirect greenhouse gas emissions in response to Glastir Efficiency Grants funding and assessing possible confounding effect of climate change on greenhouse gas emissions. Soil and freshwater analysis reports on Year 1 data only due to the time required for biodiversity assessment. An analysis of 7 ecosystem services and their potential trade-offs was carried out including the development of a metric to estimate area of land mitigating runoff/flood. Work also included a major new and completed piece of work involved developing new methods for mapping and assessing the condition of peat soils of Wales and their potential contribution to reducing greenhouse gas emissions.

Future plans for Years 3 and 4

Year 3:

- The field survey for Year 3 is already underway with 75 squares selected for survey.
- A decision regarding the inclusion of Countryside Survey squares into the Wider Wales Survey of GMEP will be sought
- Finalisation of the new High Nature Value (HNV) Farmland indicator.
- Development and launch of the GMEP Data Portal at the Royal Welsh Show 2015.
- Reporting of metrics needed for the new agreed 6 Strategic Objectives and Targets for Glastir under development by the Welsh Government. These metrics together with high level indicators for the 6 Glastir Outcomes will be used to provide annual updates through the GMEP Data Portal.

Year 4:

- Completion of the final 75 1km field survey squares to complete the 300 GMEP baseline 1km survey squares will be undertaken.

- Repeat of the Farmer Practice Survey in the summer of 2016 to identify actual changes on the farm and any benefit to farm and forestry profitability and resilience.
- Modelling work to identify benefits of Glastir for water quality in Water framework Directive catchments based on changes quantified in the Farmer Practice Survey of summer 2016 for reporting in Spring 2017
- Farmer interviews combined with modelling to quantify benefits to direct and indirect greenhouse emissions by farm type.

Highlights from Year 2

The following represents a high level summary of some of the key findings structured by Glastir outcome with additional sections added for analysis of Glastir uptake, peat soils, High Nature Value farmland and Ecosystem trade-offs and opportunities. Many others results can be found in the full report or in the GMEP Data Portal www.gmep.wales.

Analysis of Glastir Uptake

4,911 unique entrants were identified as having joined the scheme by Dec 2014, 22% of all landowners registered with LPIS in Wales. Grouped by agricultural small area, the percentage of LPIS landowners subscribed to Glastir varied from 4% to 51%, with the highest proportions present in Snowdonia (Figure 01). The total area covered by Glastir options is 3,263 km^2, 19% of the available LPIS area and 16% of the total Wales land area. Of the 4109 Glastir entrants, 84% subscribed to options under Entry Level, Advanced, or Woodland Management. Across Wales, 190 unique Glastir options codes have been taken up, including 3,050 km of linear options.

Uptake of Glastir applied most to biodiversity, which had the greatest values for all metrics except parcel area with (62% of land parcel counts), where climate change mitigation was the Outcome with most area under options (80% of land parcel counts). The Woodlands Outcome had the fewest entrants, parcels, and total area, although with average values for the number of option codes and option length. These assessments are based on allocation by the project team as the actual intended outcome of the payments intended by the Glastir Project Officer was not available at the time of writing this report.

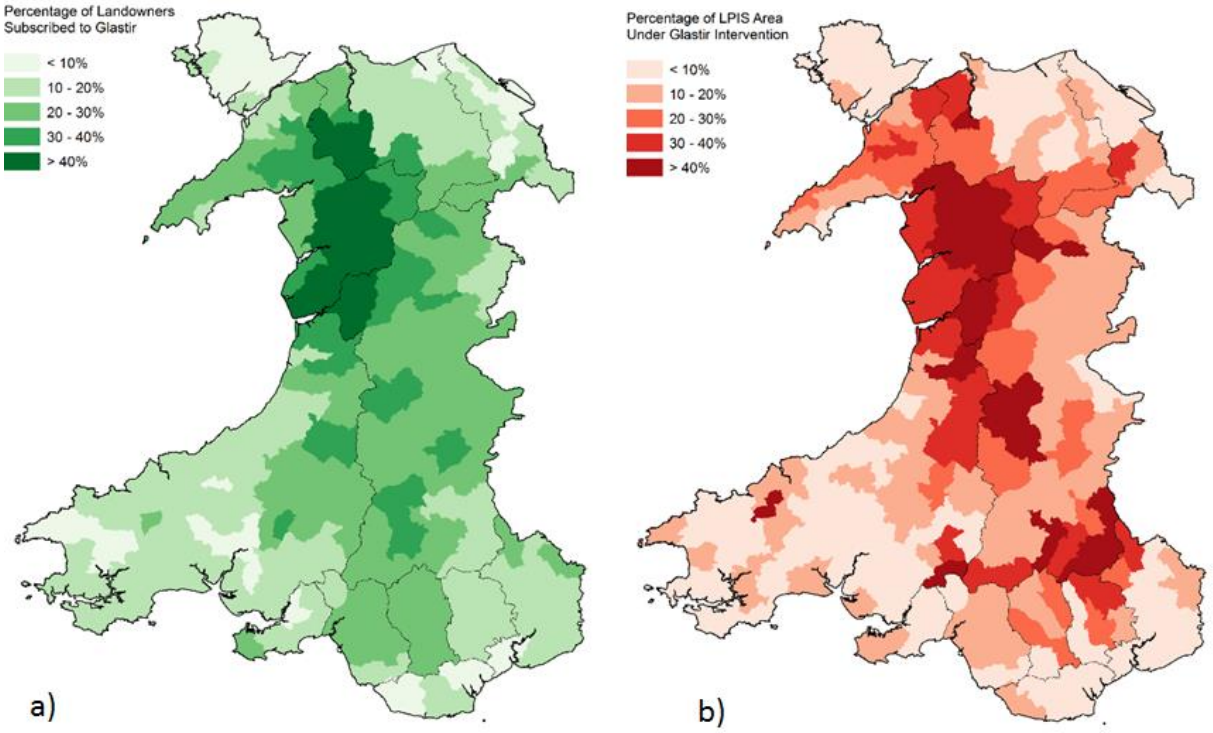


Figure 01 *a) Percentage of LPIS landowners that have subscribed to Glastir, aggregated by agricultural small area; b) Percentage of LPIS landowner area that overlaps with Glastir uptake parcels, aggregated by agricultural small area.*

If the levels of uptake are compared to amounts of points available, clearly points have driven uptake with only 308km2 (ca. 1% of Wales) where there was high uptake in areas with low points. However, there was 3041km2 (ca. 15% of Wales) with high points where there was little or no uptake (Figure 02). To try and identify if there was any consistent pattern of land not coming into scheme, we analysed the land according to its habitat type. Broadly similar proportional amount of the dominant Broad Habitat land was present occurred in the extremes of this assessment i.e. high uptake / low points versus low uptake / high points i.e. the two classes were linearly related suggesting there was no consistent bias of land coming in, or not coming in, to the scheme. The one exception was coniferous forest which was an outlier. There was proportionally a larger area with little uptake despite high points and proportionally lower area of land with high uptake and low points relative to the other 7 major habitat types. The issue of poor uptake of the Woodland Creation scheme which this data would support is further addressed in the Socio-economic Benefits section.

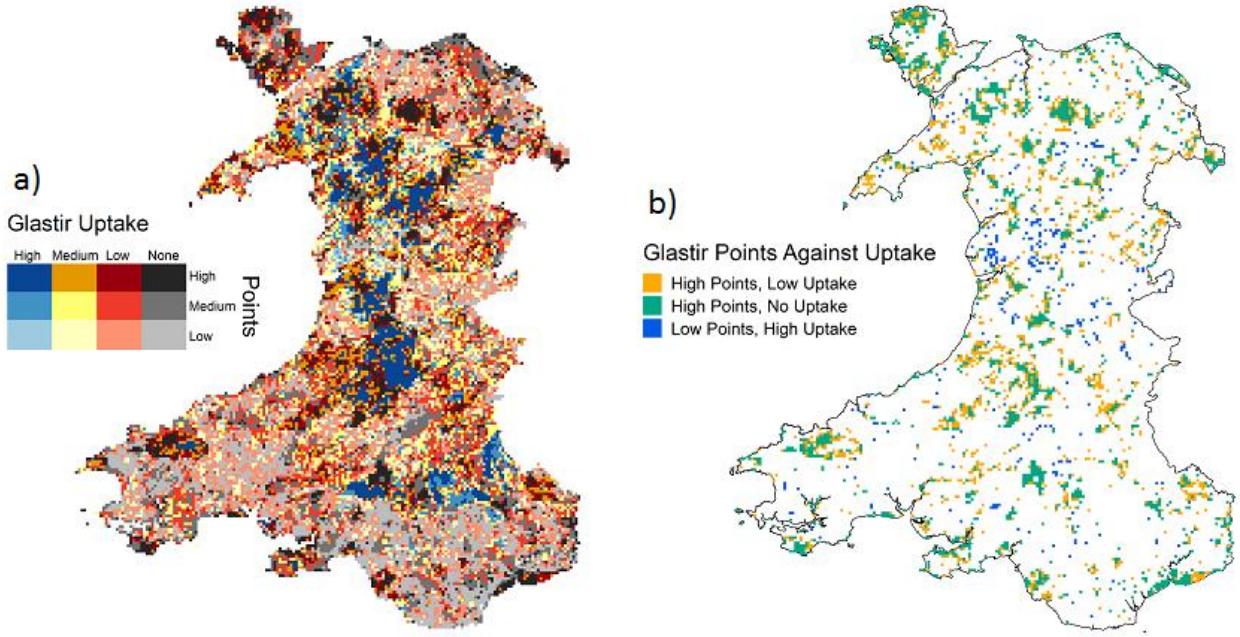


Figure 02a *Comparison of uptake by farmers compared to total points available across all outcomes;*
Figure 02b *Simplified figure highlighting the extremes of Figure 02a.*

Coverage by GMEP of Glastir

In total, 197 of the 260 GMEP squares (76%) currently selected or surveyed (Years 1-3 and Wider Wales element of Year 4) overlap with some form of Glastir uptake parcel. Squares distribution is shown in Figure 03. This includes 1,609 individual parcels belonging to 321 Glastir entrants and covering an area of 63 km^2. From the 171 squares that overlap with options parcels, a total of 88 different options have been surveyed, including 38 km of linear options.
Split by Element, the GMEP field survey capture of Glastir uptake follows the national trend, with Glastir Entry being the most surveyed Element for most metrics, followed by Organic. The lower uptake Elements of Woodland GEG overlap with the fewest squares. More Glastir Advanced parcels have been surveyed than those of Commons, although the large parcels of the common land mean the total area surveyed is larger.

By Outcome, the overlap within GMEP squares indicates a similar skewed distribution compared to uptake numbers with the majority capturing biodiversity options with 78% of land parcels with biodiversity options (62% in the scheme). Woodlands did however have the lowest coverage at 16% (10% in the scheme). This analysis will need repeating now the data has come through which includes the intended outcome for the options within the Glastir contracts. Current assessment was based on likely target outcome by the GMEP team.

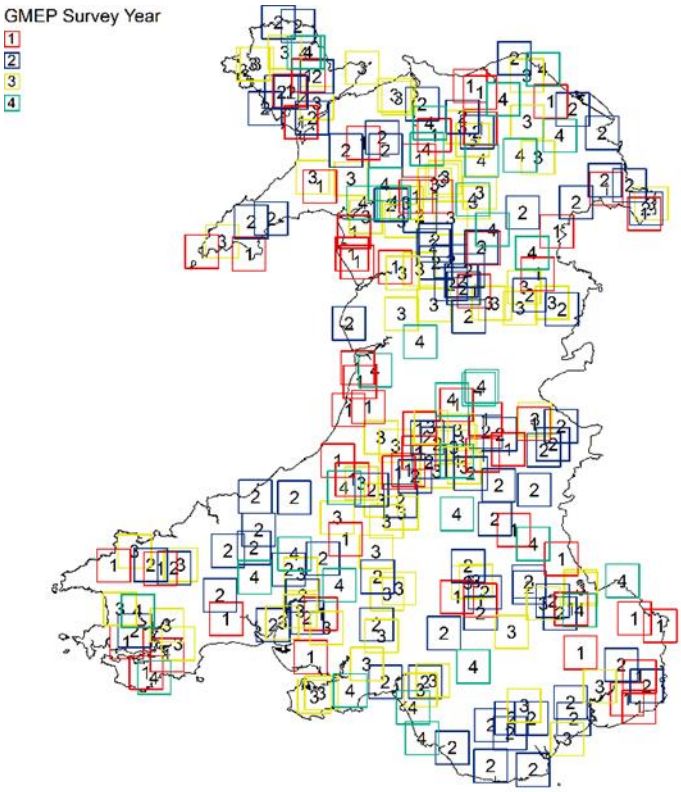


Figure 03 *Distribution of GMEP 1km survey squares but enlarged to cover 10km grid to protect locations. Squares include Years 1-3 Wider Wales Survey and Targeted Survey but only Wider Wales Survey for Year 4 as Targeted Survey will be selected according to uptake in autumn 2015.*

Aside from the field survey data, and internally-generated derived data, a range of third party data has been acquired from the Welsh Government and other sources for the project, currently including over 700 individual files which will help with future analysis.

Field survey update

The 2nd year of the rolling national surveillance monitoring programme to quantify on-going change in the Welsh countryside and impacts of Glastir options was implemented from April through to September 2014. The main biophysical survey of 90 1km squares was managed by CEH; pollinator surveys (butterflies, bees and hoverflies) were managed by Butterfly Conservation (BC); and bird surveys were managed by the British Trust for Ornithology (BTO). A full time Farmer Liaison Officer employed by CEH coordinated the movements of all field teams and arrange land access permissions. 68% of landowners contacted who had landholdings with the GMEP 1km survey squares gave permission to survey, 5% refused access, with the remainder providing no response. In total 80% of land within the 90 1km survey squares was surveyed in 2014. This co-located integrated programme of monitoring and survey which includes measurement from soils to greenhouse gases and waters, plants to birds and pollinators, landscape to historic features and landscape perception enables the inter-dependencies between these elements to be explored in future reports. It is consistent with the aims of the Environment Bill to develop more integrated approaches to

managing our natural resources in a more sustainable way. As for Year 1, survey measurements included mapping of habitats, linear and point features, recording of plant species within permanent vegetation botanical plots, topsoil sampling, headwater and pond survey and sampling, bird and pollinator surveys, landscape photography, historic feature and footpath condition assessments. All data is held within the GMEP secure Oracle spatial database. Despite every effort to ensure consistency between field surveyors by rigorous training, detailed methodologies outlined in the field handbooks, quality control and frequent communication, there will inevitably be some variation. It is therefore important to produce a quantitative measure of consistency and reliability of the data. As such, a Quality Assurance exercise was carried out to capture and understand this variation and to ensure that there was no significant bias in the data collected. See Year 1 report for full details (Emmett et al. 2014). Six GMEP squares were also re-surveyed for Quality Assurance in Year 2 (2014). See Appendix 1.1 for full Quality Assurance report.

Peat soils

Peat soils cover 4.3% of Wales, and support nationally and internationally rare bog and fen habitats. In the uplands, blanket bogs form in waterlogged conditions, and contain peat-forming plant species such as Sphagnum mosses, as well as characteristic species such as heather and cotton grasses, and rare species such as sundews and cloudberries. In addition to their importance for biodiversity, peat soils act as Wales' largest terrestrial ecosystem store of carbon, and in good condition have the potential to contribute to climate regulation through ongoing CO_2 sequestration. However, Welsh peat soils have been detrimentally impacted by centuries of human activity including drainage, over-grazing and conversion to grassland and forestry. As a result Welsh peat soils are currently thought to act as a source of greenhouse gas (GHG) emissions. Measures supported through Glastir aim to reduce these emissions, and to restore the carbon sequestration function of Welsh peat soils, through a reduction in land-use pressures on a range of both upland and lowland bogs and fens.

Highlights from Year 2

In year 1 of GMEP in addition to the core survey activities, work undertaken included the mapping of the extent of peat erosion across Wales from aerial photographs, and an assessment of whether satellite data could be used to monitor changes in the surface elevation of peat soils that would indicate whether they were accumulating or losing carbon. In Year 2, we have undertaken a detailed new assessment of the extent and condition of the full Welsh peat soil resource, based on an integrated analysis of soil mapping data, land-cover data and the use of aerial photographs to identify and map drainage ditches. We have also collected a large number of peat cores, which are being used to measure rates of peat accumulation over the last century as a function of land-use.

Main Findings

- A new unified peat map has been defined for the GMEP project which should allow a more reliable assessment of the state of the Welsh peat resource as a whole, with better representation of lowland peats, and more accurate targeting of Glastir peat soil-related measures on those areas where peats are present (Figure 04).
- This map has now been passed to Glastir Contract Managers to use when negotiating new Glastir Agreements.

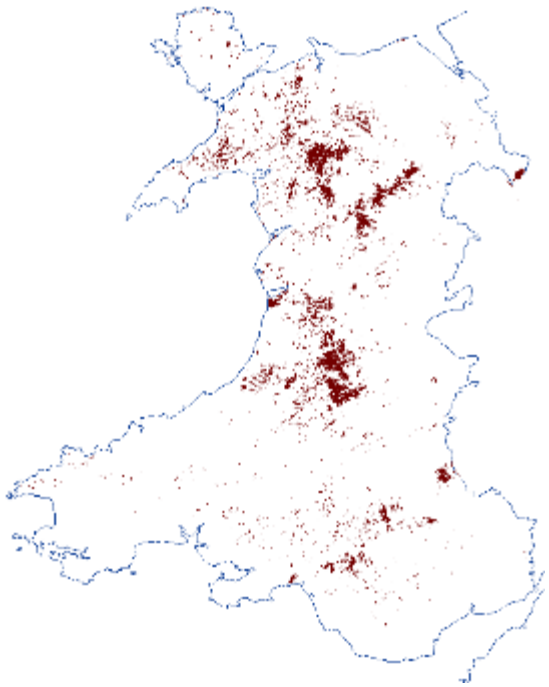


Figure 04 *A unified peat map for Wales, based on combined BGS and NRW data*

- Based on this new 'unified' Welsh peat map developed, peat soils are estimated to cover over 90,000 ha of Wales (4.3% of the total land area) of which 75% is in upland areas, and 25% in lowland areas
- Digital processing of aerial photographs suggests that there are at least 3000 km of drainage ditches on peat soil in Wales
- Overall, around three quarters of the Welsh peat soil area is thought to have been impacted by one or more land-use activity, including drainage, overgrazing, conversion to grassland and afforestation with only 30% in 'good condition' with 25% 'modified' into grassland and 10% into woodland.
- As a result of these activities, Welsh peat soils are currently estimated to be generating 'anthropogenic' emissions of around 400 kt CO_2-equivalents per year (equating to around 7% of all Welsh transport-related emissions). This compares to an estimated natural 'reference' condition (i.e. if all the currently mapped peat area was natural bog or fen) of approximately 140 kt CO_2-eq yr^{-1} (Figure 05).This indicates that natural peat soils are net emitters of greenhouse gas equivalents primarily due to the radiative power of methane. They store carbon overall if in good condition (or peat would not accumulate) and it is the protection of this carbon store and avoidance of emissions which is the objective Glastir can contribute to. As Glastir payments are targeted on semi-improved peats only, the potential emission reductions which could be achieved if all semi-improved peat soils could be returned to the reference state is estimated at 150 kt CO_2-eq yr^{-1}.
- Between 1990 and 2007 there was a decline in species richness in blanket bogs, but a slight increase in the number of characteristic ('positive indicator') bog species (positive CSM indicators).
- Fifty peat cores have now been collected from around Wales in order to measure how much CO_2 Welsh peats were able to sequester in the past, and how much this has been affected by recent agricultural management and forestry.
- Our recommendation is that these new findings should be used to revise the scheme as it goes forward to maximise benefits of Glastir payments for emission reduction from peat soils.

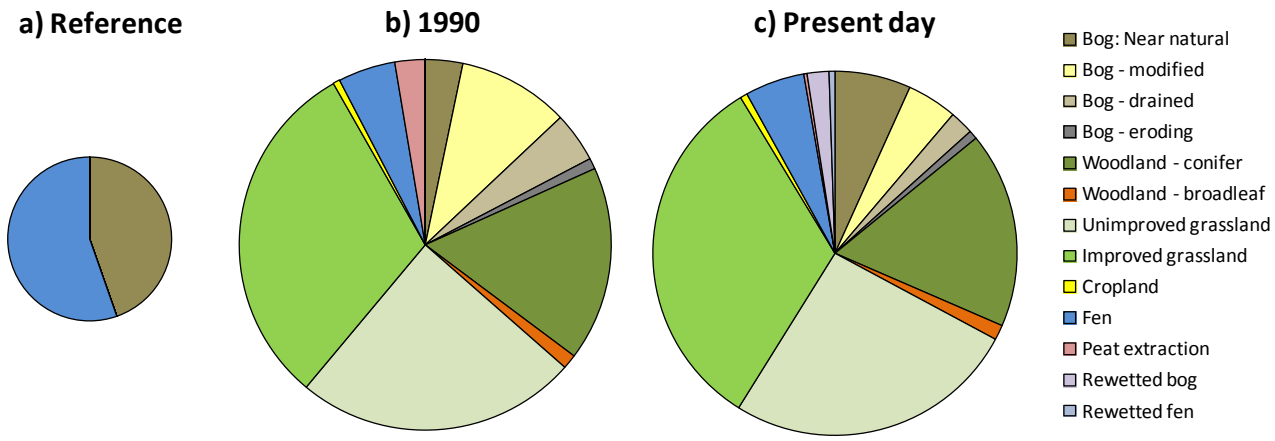


Figure 05 *The estimated contribution of different peat land-use/condition categories to total greenhouse gas emissions from Welsh peats under a natural 'reference' condition, in 1990, and at present day. The size of each pie chart is illustrative of the overall level of emissions.*

Overall the picture is one of highly modified peat soils across Wales ca. 75% .The only recent improvements are in the cessation of peat extraction (Figure XX) and in the condition of bogs i.e. using plant species as a proxy for bog condition, between 1990 and 2007 there was a slight increase in the number of characteristic ('positive indicator') bog species presumably due to recent targeting of bogs for restoration.

Socio-economic Benefits

GMEP undertakes a range of activities to capture the wider socio-economic benefits of the Glastir scheme. These benefits may arise from a range of Glastir activities including payments from farmers into the local community for labour or services to more indirect pathways such as an improved visual landscape quality which has the potential to benefit both local communities and the tourism industry. More generally it is hoped the greater protection of our natural resources intended from Glastir payments will contribute to the 'Resilient Wales' Goal of the Well-being and Future Generations Bill.

Activities in this area in Year 2 have included:

- An assessment of the benefits of the Glastir Efficiency Grants to the wider community and the potential impacts on farm carbon footprints;
- Understanding the barriers to uptake of the Woodland Creation Scheme
- Developing objective, transparent and repeatable measures for assessing the visual landscape quality to enable the impact of Glastir to be assessed in the future
- Quantifying accessibility the landscape both in terms of physical accessibility through the Public Rights of Way network (PROW) and a derived measure of visual accessibility which takes account of the view as experienced by the public within the landscape.
- Continued assessment of the condition of the historic assets present such that future **i**mpacts of Glastir can be assessed.

***Highlights from Year 2 include**:*

Wider Socio-Economic Effects of Glastir Efficiency Scheme Grants

- There is interest within the Welsh Government to identify the wider benefits of Glastir beyond the landowner is receipt of the payment. A survey was carried out to explore the wider benefits of the Glastir Efficiency Grants as a case study to explore this issue.
- A total of 305 grants were approved for farms in the survey (July 2014). Energy Efficiency grants accounted for 9.2% of total approved grants, 7.9% were assigned to dairy farms, 1.3%

to ‘other’ farms and none to LFA cattle and sheep. Grants awarded to LFA cattle and sheep farms were nearly all for Slurry and Manure Efficiency (174 of the 179 approved grants).

- The total monetary value of the paid grants amounted to £1,006,490. No Water Efficiency grants were in progress by July 2014. Slurry and Manure Efficiency grants accounted for £883,000, and Energy Efficiency grants, £123,490.
- Lowland dairy farms received the largest grant per farm on average (£16,102), compared to £9,855 for LFA cattle and sheep farms and £8,732 for LFA dairy farms. The smallest size category of farms (0-19.9 ha) received the smallest average grant of £8,370.
- More than 90% of respondents agreed that Glastir Efficiency Grants (GEGs) had encouraged them to undertake new capital investments. Similarly, the majority of farmers (83%) agreed that access to GEGs increased their scale of planned investment. Over 87% of farmers agreed that their funded project would not have happened without the grant, suggesting that GEGs has provided a useful tool for delivering economic development and encouraging new on-farm initiatives.
- As a consequence of the GEGs grants more than a quarter (28%) of farm businesses reported a general increase in sales with 51% reporting an increase in sales from farming specifically.
- Increased farm expenditure was spent within Welsh industries (68%), Welsh households (18%) and taxes (8%) with the remaining 6% unaccounted for due to respondent survey error (Figure 06).
- Of the expenditure that respondents allocated to imported materials, the majority was for building materials (49%), and machinery and equipment (32%). Of these imports, 57% of spending was within the UK and Ireland; 8% reported a mixture of spending throughout the UK and European countries and 13% imported products from other European countries.
- According to 71% of respondents, GEGs grants have promoted a beneficial effect on farm suppliers across all farm types. Similarly, 44% of respondents stated that farm customers and clients had experienced beneficial financial effects from the grants.

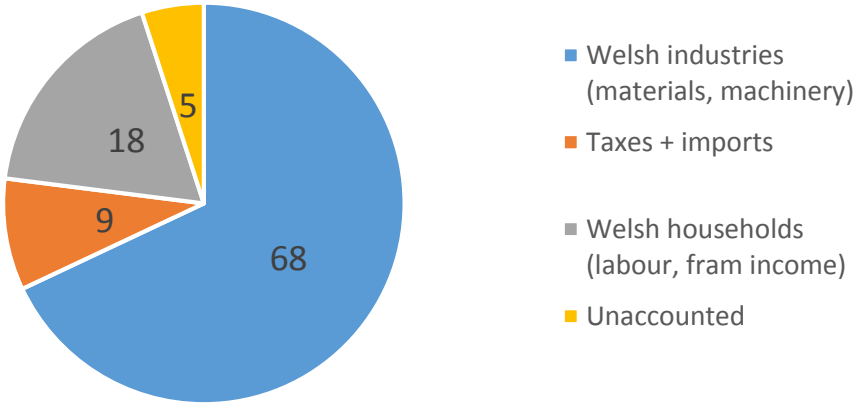


Figure 06 *Allocation of increased expenditure following receipt of GES grants.*

Understanding Barriers to Uptake of Woodland Creation Schemes

- Woodland creation is an activity promoted by Glastir to increase carbon sequestration and thus reduce overall GHG emissions from the land sector. However, uptake of the scheme has been low and a GMEP survey was designed to identify the barriers to uptake.
- The results indicated that the process is perceived to undermine the scheme objectives and acts as a disincentive for potential scheme members from both the farming community and the Local Authorities.
- Recommendations to improve uptake include:
    - To achieve greater scheme uptake the application process should be simplified.

- The scheme needs to be more flexible to account for external influences.
- The auditing process needs to be less threatening, and penalties need to be clearly communicated to encourage greater uptake.
- Payment rates need to be clarified to encourage potential members to adopt the scheme.

Landscape and historic environment

For a relatively small nation, Wales contains a remarkably diverse range of landscapes; from the coasts to the moors, the farmed to the industrialised. The unique physical characteristics of the landscape which derive from its diverse topography, geology, soils and climate have all helped to create a valued cultural and historic landscape which encompasses farming, rural buildings, towns as well as unique historical sites and industrial archaeology. The 3.1 million residents, the majority of whom live within the urban conurbations of south Wales (Cardiff, Swansea) and along the north coast and the fringes of the Dee Estuary are dwarfed by the 100 million day visits and an estimated 6 million overnight trips made to Wales by recreational visitors in 2013.

Wales also has a rich and distinctive historic environment. There are currently 3 UNESCO World Heritage Sites, 30,000 listed buildings and over 4,000 Scheduled Ancient Monuments in Wales which are protected by law. It has been estimated that the historic environment supports over 30,000 jobs and in 2009 contributed approximately £840 million to the wider economy. The historic environment also creates social benefits for residents of Wales, including opportunities for leisure, volunteering and learning. The HEF dataset records the location and known information about these non-designated historic features. Together with the designated sites such as the Scheduled Ancient Monuments and listed buildings, these smaller features contribute to the overall historic and cultural value of a landscape. Non-designated historic features are common throughout all landscapes in Wales. On the whole, these features are found on private land so the long-term care of these cultural assets is frequently entrusted to individual landowners. Sometimes these features face neglect or suffer damage through lack of appropriate knowledge and management. Glastir provides funding to landowners to protect historic features through land use management such as switching from arable cropping to grass pasture or managing erosion by controlling stock better with fencing. In addition, payments are available to help manage scrub which is a particular problem on some historic sites. This type of active management has potentially positive impacts on visual landscape quality, where sightlines are clear, historic features can be seen and recognised as such by the general public.

Glastir explicitly recognises the importance of the Welsh landscape; one of the five stated aims of the programme is to manage and protect the Welsh landscape and the historic environment therein, whilst retaining and promoting public access. Four specific landscape targets are outlined in the programme including: ditch landscapes; historic features and landscapes; pond landscapes and protected landscapes. An additional five targets have significant landscape quality components and include those relating to orchards; parkland and wood pastures; parks and gardens; permissive access and woodland. Within each of these targets are specific management options which have direct impacts on the potential quality of the landscape view. Whilst existing datasets provide information on the location of historic features present within Wales, GMEP is providing an insight into the condition of those features within the GMEP 1km survey squares, the pressures they currently face and eventually will indicate how this changes over time.

Major achievements in Year 2

- A GMEP Visual Quality Index (VQI) has now been successfully run on the 150 1st and 2nd year GMEP 1km survey squares. This has generated a data listing all of the 23 input parameters by square and weighted index values for each. Each of the survey squares has now been ranked from 1 (highest quality index) to 150 (lowest quality index).

- Viewshed analysis has been completed at 3 scales for 150 1st and 2nd year 1km survey squares using 4 different categories of users (pedestrians, cyclists, small vehicle users, rail users) for 3 different scales: looking within the 1km square, looking out to the surrounding 3 x 3 km, looking in from the surrounding 3 x 3 km square. This equates to 1800 separate viewshed datasets for the two years.
- Condition assessment data has been collected and analysed for the historic environment features of the 150 1st and 2nd year GMEP 1km survey sites.
- Number and condition of Public Rights of Ways in the Year 2 GMEP squares have been assessed.
- Photographic preference survey pilot undertaken early spring 2014, the online survey was then refined and launched summer 2014 with both English and Welsh versions available. Currently, over 1360 surveys have been completed online with approximately 10% of these completed in Welsh. The PPS has validated the VQI ranking process and has provided further information about the positive and negative impacts of specific components of the VQI. Our initial target was 500 completed surveys, so this has exceeded our expectations significantly and has generated a dataset of wider significance and value.

Main findings

The range of VQI across the Welsh landscape

- A new Visual Quality Index (VQI) of landscape was developed by GMEP in year 1 to try and capture objectively Welsh landscape quality using a method which could be repeated and analysed robustly alongside the many other natural resource metrics within the survey. In year 2, we have started to explore how this index varies across the Welsh landscape to provide a baseline for future assessments of the effect of Glastir payments.
- There is no significant difference in VQI between upland and lowland sites. However, the upland landscapes have a smaller range of VQI values and a higher overall median value which indicates that they tend not to include the lowest quality landscapes. It is only where a range of positive values coincide that very high landscape quality scores prevail.
- There is no statistical difference between the mean quality ratings assigned to the 1km sites which fall within / without of a protected area. However, there are clear differences in the range of values, with all the highest values falling into protected areas (Figure 07).
- Squares which contained areas of Glastir land were compared against those with none. Although there was some indication that those sites with higher VQI values were found within the Glastir managed scheme, the results were not significant to date. As more squares are surveyed this trend may become clearer (Figure 07).
- Currently, no relationship is found between the landscape quality rating and the number of plant, bird, butterfly or bee species in the GMEP Year 1 and 2 1km survey squares suggesting there is no direct relationship between ecological and landscape quality as indicated by these initial test metrics. However, a more systematic and integrated approach, e.g. using the High Nature Value Farmland index currently under development, will be assessed in future years which will also benefit from a greater sample size.

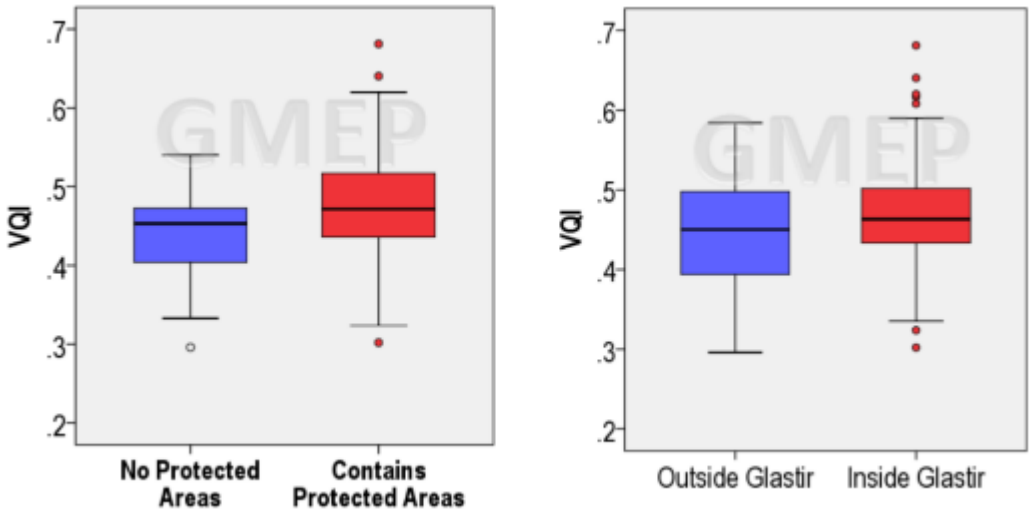


Figure 07: *The VQI of the 1st and 2nd year GMEP 1km survey sites (n= 150) comparing a) inside and outside of protected areas and b) squares with some Glastir managed land as compared against those within none.*

Countryside visiting habits and its importance

- The majority of the 1,360 respondents to the GMEP photo preference survey were well spread across Wales (with additional responses from other parts of the UK) (Figure 08).
- Respondents visited the countryside either daily or two to three times per week.
- The top five reasons for visiting the countryside were: '*relaxation*', '*active recreation'*, '*health reasons'*, '*peace and quiet*', and '*to explore and discover new places'*.
- Private car was the most common way of getting to the countryside, followed by walking.
- The vast majority of respondents considered the Welsh countryside to be either 'important' or 'very important' to them.

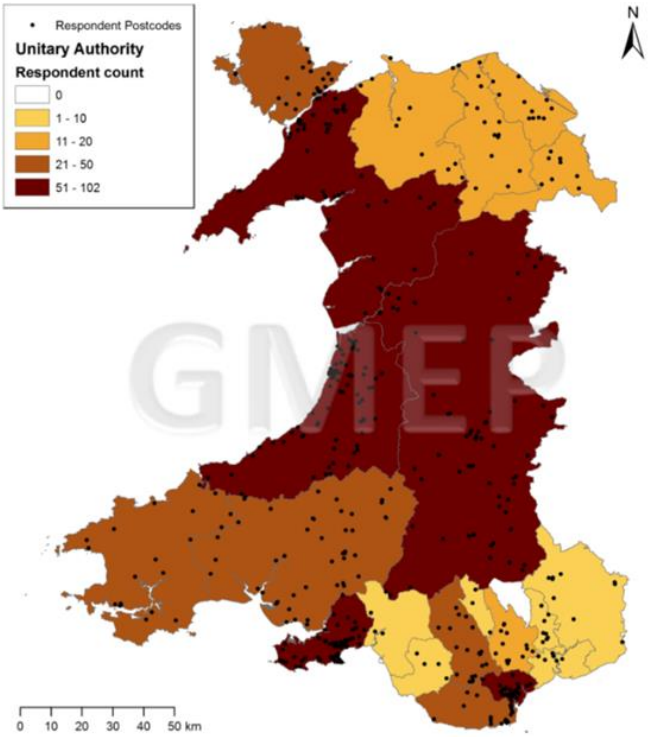


Figure 08 *Distribution of survey respondents from within Wales. Of the 976 completed surveys, 758 described themselves as Welsh (78%)*

Overall attractiveness from the photographic preference survey

- The overall order of landscape attractiveness indicated by the respondents is largely similar to the order indicated by the VQI.
- The ranking of landscapes by females and males were generally similar.
- No major differences could be found in landscape rankings by the different age groups: all age groups (except those between 30 and 44) ranked the five landscaped in the same order. However, younger respondents gave lower overall ratings than the older groups.
- The mean rating scores indicated that respondents who considered themselves Welsh, English, British and Northern Irish ranked the landscapes in the same order. However there was a small but statistically significant difference in the ratings for one type of landscapes between respondents who considered themselves Welsh relative to those considering themselves British, English or other nationality.
- The type of locations where respondents grew up in had a small but statistically significant impact on ranking of landscape types. Respondents who grew up in a village tended to differ in some ranking some landscapes relative to those who grew up in a small town or a town (for E). No effect of current home was found.

Appreciation of specific landscape features

- In some landscapes, single features dominated assessments e.g. the sea shore or flowering heather. For other landscapes, multiple areas were favoured particularly deciduous trees/woodland, hedgerows, river and valley in the distance.
- 'Natural' features such as meadows, deciduous trees, woodland and water features were liked by the majority of respondents, as were livestock and less 'intrusive' man-made elements such as stone wall and small farmstead.
- Less conclusive were opinions towards the more prominent man-made features such as conifer plantations, road and large farm buildings. While a substantial proportion of respondents disliked them, these were never an overwhelming majority as notable proportion of respondents also liked these features or marked them as 'neutral' e.g. Figure 09.

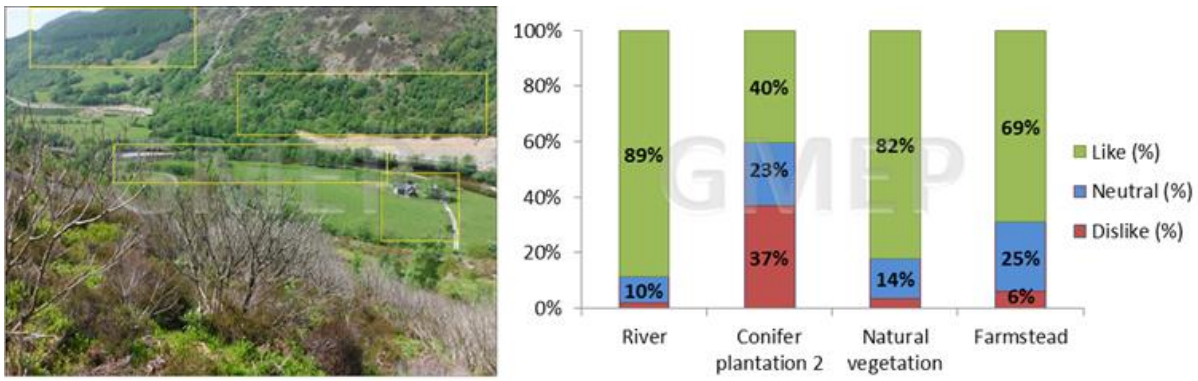


Figure 09 *One of the landscape photos used in the landscape preference survey with the preferences indicated.*

Visual and physical access of the landscape

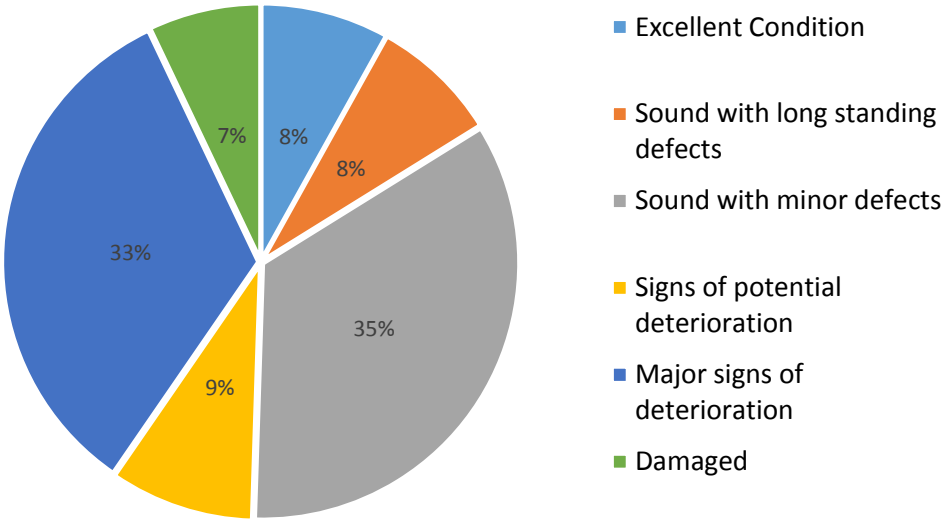
- Walkers and cyclists enjoy on average a view of 45% of the 1km square compared against 36% of people confined to a car.
- At the wider scale of the surrounding 3 x 3km landscape from within the 1km square again, pedestrians have most access to these wider views with on average 40% of the surrounding region being visible.
- From outside of the 1km square, the GMEP 1km survey squares also contribute to the landscape in which they are sited. 81% of the pedestrian group could view the squares which reflects the overall density of roads and footpaths in Wales.

- Of the first and second year sites, the digital data show that 133 of the 150 contained some Public Rights of Way (PROW); the remaining 17 sites were all remote, upland sites. The distribution of paths varied significantly, but in places the network was dense with one site having nearly 6km of footpaths within the 1km^2, though more typically this figure was between 1.5 –3km.
- Condition surveys found that 57 of the 90 Year 2 sites had some PROW of which only 20 had fully open, signed and navigable paths. In a typical 1km square, only two-thirds of the paths on a 1km site were fully open, physically accessible and easy to find. Poor signage was common and many footpaths were infrequently used as a consequence which led to degradation and poor maintenance.

Condition of historic features

- An assessment of condition shows that 8% were judged to be in excellent condition at the time of survey and 35% were seen to be sound with minor defects. However, 33% were assessed to be showing major signs of deterioration while a further 7% were seen to have significant damage.(Figure 10)
- Vegetation was the most prevalent threat (including scrub, bracken, brambles and rushes), with potential to not only visually obscure but also physically damage historic features Stock threats were also relatively frequent (including poaching, erosion and stock wear) while agricultural (for example surface tyre tracks, dumping, ploughing, drainage and pasture improvement) and other general threats (including natural decay, vandalism, development, flytipping) were less common. (Figure 11)

Figure10 *shows condition of Historic Environment Features (HEF's) from years 1 and 2 of GMEP 1kmsurvey squares.*



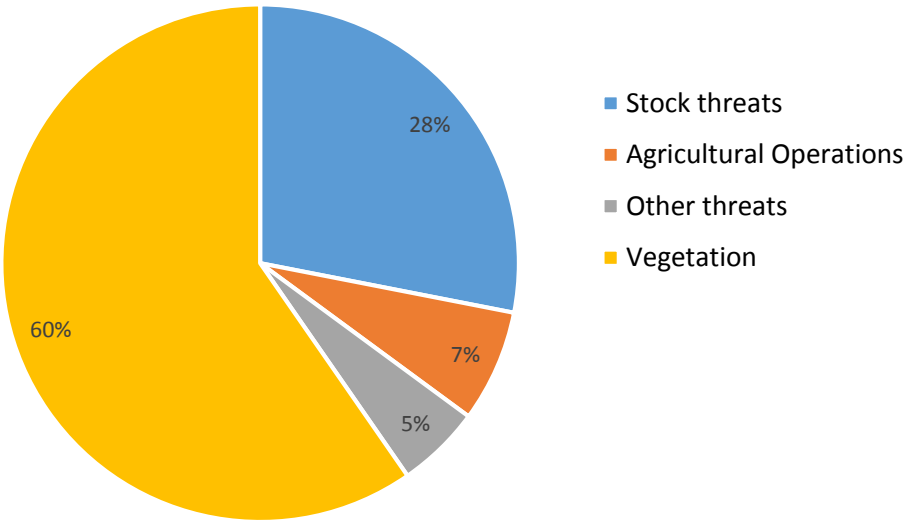


Figure 11 *shows threats to Historic Environment Features (HEF's) or years1 1 and 2 of GMEP 1km survey squares.*

Woodlands

Woodlands are important for the provision of multiple Ecosystem Services, goods and benefits including timber, soil protection, flood prevention, recreation, climate regulation and wild species diversity (for both generalists and woodland specialists). Many of these services are additive and there are synergies between services rather than trade-offs, woodlands are multi-functional habitats. The environmental benefits of woodlands in Wales have been valued at £34 million. A recent survey demonstrated that nearly 65% of people in Wales visit Welsh woodlands regularly and 94% believe they provide a definite benefit to the local community. Of the UK countries, Wales has the highest percentage cover of Broadleaved, Mixed & Yew Woodland although this is low by European standards, only Scotland has a higher total woodland cover however this is a consequence of the much higher percentage cover of Coniferous Woodland there than elsewhere. About 210 (39%) of the Section 42 species of principal importance for conservation of biological diversity in Wales either rely on woodland habitats, or could potentially be affected by silvicultural operations. The Welsh Government strategy 'Woodlands for Wales' was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales's strategy. In Wales, the Glastir scheme is a significant component of the Rural Development Program and therefore contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity derived from agreements at global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act) which will apply to woodland habitats. Glastir has a specific woodlands element which includes options on creating and managing woodland. GMEP has also undertaken a survey of landowners intended to identify barriers to the uptake of the Glastir Woodland Creation scheme.

Main findings

Woodland extent

- The main finding of Year 2 included an increase in the area of woodland in Wales over the past thirty years with an increase to 2014 (recorded by both GMEP and the National Forest Inventory). Both Broadleaved and coniferous woodland types have increased in area (Figure 12). Note that neither GMEP nor NFI provides a complete picture of historical or current trends but should be selected depending on the question being asked as their methods are

more relevant to some questions than others e.g. area of restocking (NFI), area of small woodland (GMEP) etc.

- GMEP estimates the total area of all woodland in Wales to be 346 000ha (187000ha Broadleaved and 159 000ha coniferous woodland), this is 16.3% of Wales in 2013/14. This compares to 10% in England and approximately 15-18% in Scotland.
- The National Forest Inventory estimate the total area of all woodland in Wales in 2014 to be 306 000 ha, 14.8% of Wales, 156 000ha of which is Broadleaved woodland and 151 000ha is coniferous.
- The total area of woodland in Wales is consistent between Countryside Survey/GMEP and National Forest Inventory (particularly considering the large confidence intervals for the estimates), the figure for coniferous woodland is very similar (GMEP 159 000ha, NFI 151 000ha) Countryside Survey records a greater amount of woodland as Broadleaved, Mixed & Yew Woodland relative to Coniferous Woodland.
- The National Forest Inventory estimated new planting and restocking in Wales to be 3 100 ha between the two periods 2009-2010 and 2013-2014. This is less than in previous years and a small proportion of the UK new planting (50 900 ha) the majority of which was in Scotland.

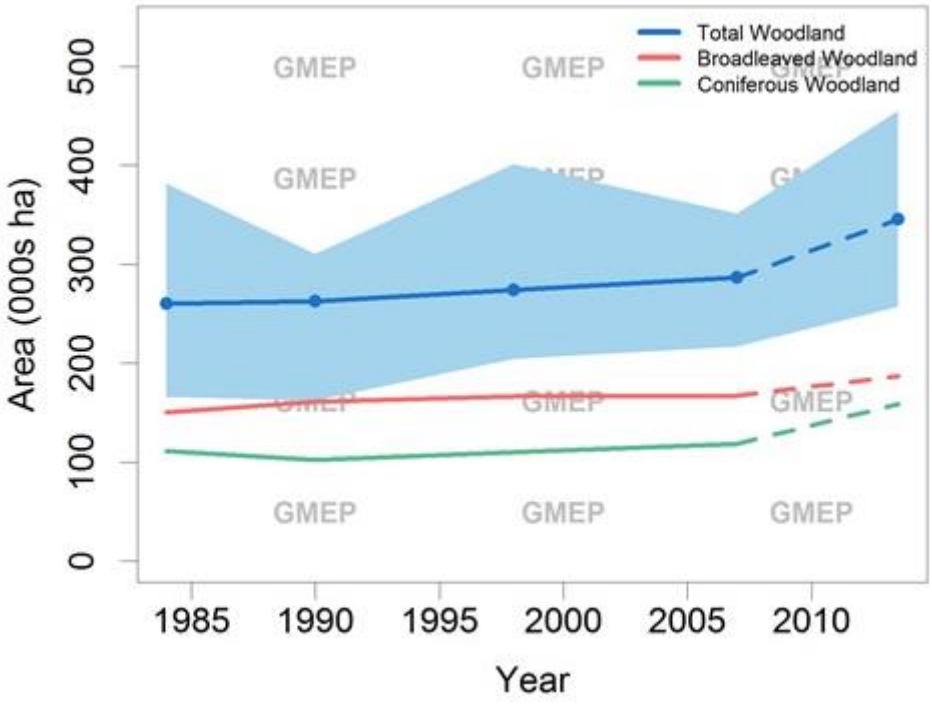


Figure 12 *The area of woodland in Wales over time, created by national estimates from field survey from Countryside Survey (solid line) and GMEP (dotted line) data.*

Woodland condition

- The total area of woodland known to be managed to the UK Forestry Standard has increased from 123,000 ha in 2001 to at least 203,000 ha in 2014.
- Since 2010, there have been outbreaks of two quarantine diseases affecting tree species in Wales (*Phytophthora ramorum* and *Chalara fraxinea*). A Wales specific *Phytophthora ramorum* disease management was launched in December 2013 which establishes management zones. There are also a small number of non-quarantine pests and diseases known to be affecting tree species in Wales.
- There is inter-annual variation in the woodland bird indicator but there does not appear to have been a significant directional change in woodland bird species abundance. It is relatively stable in contrast to the farmland bird indicator (Figure 13)

- Current sequestration from Welsh woodlands is estimated to be about 1,419 gigagrams (1,419,000 tonnes) annually. Forestry is predicted to remain a net sink for atmospheric carbon.
- There was a general non-significant downward trend in Ancient Woodland indicator (AWI) species in large 200m^2 woodland vegetation plots between 1990 and 2007 however the number of AWI species increased significantly in the 2013/14 GMEP sample.
- A similar trend was seen for total plant species richness in large vegetation plots (Figure 03).
- Scores for plant species preference for light are calculated as an average value per plot i.e. higher score= plants present prefer lighter conditions. There has been a decline in light score between 1990 and 2013/14 this indicates that plots are becoming more overgrown with increased shading, possibly due to less management.
- There has been no significant change in connectivity of broadleaf woorland between 1990 and 2013/14.
- No significant change in woody species diversity in hedgerows over the last 10-20 years has been observed. An increase in cutting of hedgerows has been recorded but large decline in new planting, layering and coppicing since 1990. An increase in the length of hedgerows becoming lines of trees also increased suggests a decline in management overall.
- Land coming into Glastir has a significantly higher length of hedgerows than that outside which needs to be taken into consideration in future assessments of Glastir impact.

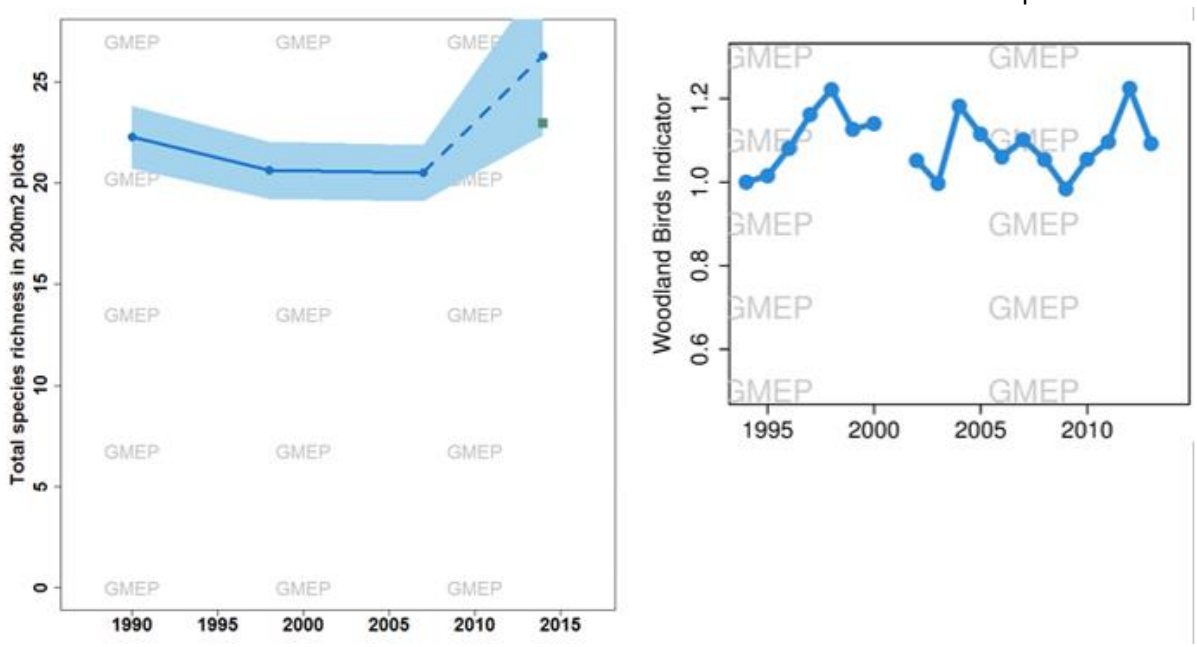


Figure 13 *Trends in mean total plant species richness in woodlands (CS/GMEP data) and woodland bird species (BBS data).*

- We describe the development of a new Woody Cover Product (WCP), which aims to map large hedgerows, individual trees and small patches of woodland, as well as larger woodland, across the whole of Wales at a 5m x 5m scale (Figure 16). The resulting product has numerous potential applications, including investigations of habitat connectivity, modelling catchment run-off processes and quantification of carbon stocks. When validated against aerial photography for several test sites the product had a classification accuracy of 88 %.

Figure 16 *A scene from the new Woody Cover Product showing the areas identified as woody cover (red areas) overlaid onto aerial photography.*

Overall the trend for woodland stock and condition indicate one of increased area but little evidence of improved condition.

Biodiversity

The conservation of biodiversity in Wales recognizes the value people place on a rich heritage of wild species and habitats. Some habitats and species have a stronghold in Wales whilst being rare or absent elsewhere in the UK and Europe so that Wales has a particular responsibility for their monitoring and conservation. While the importance of biodiversity reflects the values placed on it by people, some of these values are harder to quantify than others. They are nonetheless important, including for example conservation of wild species and habitats for their cultural, spiritual, aesthetic and recreational importance. In 2007 the Environment Agency Wales estimated that "wildlife-based activity" contributed a total output of £1.9 billion per year to the Welsh economy which exceeded the total agricultural output in 2011 of 1.3 billion. Therefore the contribution of biodiversity to prosperity, well-being and job creation in Wales should not be underestimated.
GMEP methods are particularly well suited to reporting change changes in biodiversity in the wider countryside which surround designated areas and thus provide important areas for species and habitats to connect and respond to changing environmental conditions such as climate change. In addition, GMEP has developed methods for detecting Glastir impacts on section 42 species and habitats determining the coincidence of options with species and habitats and deriving new indices of long term trends in biodiversity as the backdrop to GMEP. We are also developing methods to characterise High Nature Value farmland (see HNV Section) and to extend our estimates of biodiversity change and impacts of Glastir outside of the sample of GMEP squares and into wider Wales by integration with remotely sensed data products and biological records databases. For brevity not all national trend data are reported here but are available within the GMEP Data Portal. Data on Priority Habitats extent and condition are not yet available.

Highlights from Year 2

- The UK Butterfly Monitoring Scheme (UKBMS) data for Wales going back to 1976 has been collated for 324 1km squares and trend lines calculated. Results indicate a historic decline in specialist butterfly species with recent stability with no further decline over the last 10 years whilst there are more stable trends for more generalist butterfly species.
- The BTO/JNCC/RSPB Breeding Bird Survey (BBS) Welsh farmland bird indices from the show a tendency to declines from around 2000, while the woodland index has remained relatively stable. This reflects the continuing downward trends in a number of farmland bird species, such as Yellowhammer and Skylark. As with all multi-species indices it is worth noting within a declining indicator, it is likely that some component species will need no conservation action, but declining species may feature within an increasing trend and thus be conservation priorities.
- New metrics developed by GMEP for total abundance and diversity of target bird species exploiting the BBS data were found to be rather stable over the last 20 years. As with other indicators, however, the process of summarization will have masked some patterns of relative increase for individual species, while masking others of relative decline for other species.
- The Breeding Bird Survey (BBS) trend data were calculated for 35 of the target species and aggregated into a new 'target bird species index'. At least half of the 35 priority bird species for which there was sufficient data (there are 50 in total) were scored as increasing or stable in each of the periods considered from 1994 - 2014, but there was considerable variation in trend direction within and between species, leading to considerable variation in the overall index of population trend health. Specifically, rather more population trends were negative during 2000-2009 than at either end of the time series considered and there was no pattern for an overall improvement in population health over time (Table 02).

	1994-1999	2000-2004	2005-2009	2010-2014
Number of species with trend data	34	35	35	34
Number increasing/stable	23	21	17	22
Percentage increasing/stable	67.6	60.0	48.6	64.7

Table 02 *Summary of population trends across priority (Section 42) bird species.*

- In the future, there is good potential to monitor for change in extent for 13 Priority Habitats. Recent trends from analysis of historical data are currently being discussed with NRW. For priority bird species it is likely GMEP will be able to report on 14 species (out of 50 listed) directly from the GMEP survey data. Many others are extinct as breeding species in Wales, are nocturnal (or crepuscular) species, or are only winter visitors which are captured by other surveys. More importantly, the inclusion of bird monitoring within the same squares as all the other GMEP measurements enable the inter-dependencies between metrics plus drivers of change to be explored within GMEP which is not always possible within the more targeted surveys as the supporting data is not gathered. There may be potential for reporting on 7 of the 15 priority butterfly species.
- For other Priority species, we have developed the knowledge base required to identify sets of proxy indicator variables for section 42 species and on the derivation of these indicators from GMEP survey data. This comprises comprehensive reviews of species' ecology and establishing how species options are translated into indicators drawn from field survey attributes. These indicators measure whether Glastir options have resulted in ecological changes assumed favourable to section 42 species populations. An initial sample of 6 species were selected representing section 42 invertebrates, mammals, birds and plants focusing on

those that are more widely distributed in Wales; Dormouse, Rare Arable Plants, Curlew, Lapwing, Marsh Fritillary and the Lesser Horseshoe Bat.

- The impact of past agri-environment schemes on birds was assessed using bird population growth rates (changes from year to year) using different quantities of relevant AES management in and around BTO/JNCC/RSPB Breeding Bird Survey (BBS) 1km squares. Positive associations with Tir Gofal options were much more common than negative ones, particularly for woodland and hedgerow management, followed by arable seed provision and scrub management. The evidence therefore supports broadly positive effects of Tir Gofal, notably involving management of woodland, scrub, hedgerows and habitats providing winter seed in arable farmland (Figure 14).

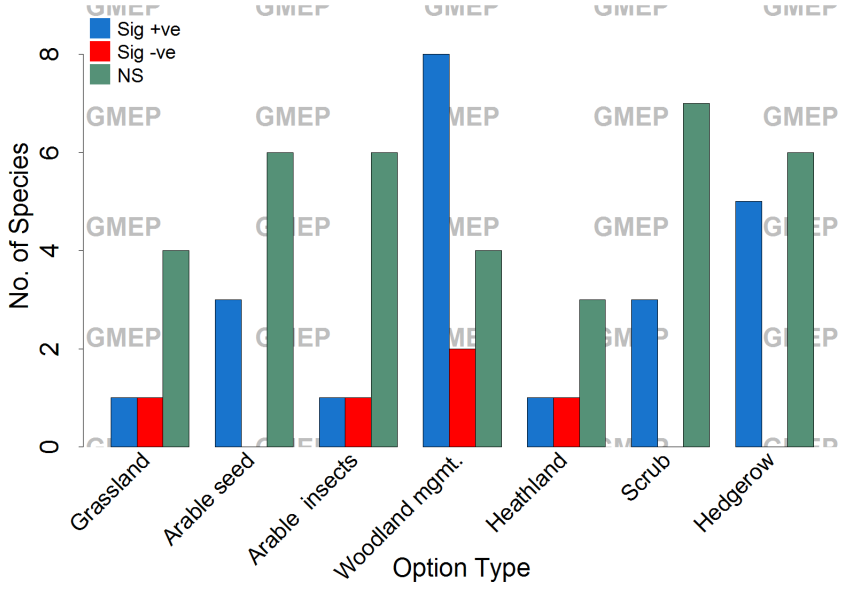


Figure 14 *Numbers of bird species with positive, negative and non-significant associations with TG option groups.*

- The legacy effect of Tir Gofal on land coming into the Glastir scheme was assessed for plant species. For the vast majority of indicators (42 out of 45) there was no evidence that plots occurring on land previously subjected to Tir Gofal prescriptions had different values to plots on land which had never been under Tir Gofal. Sample sizes were small however and the power to detect any legacy will increase as the GMEP survey continues. Despite this limited sample size, for two options there were significant differences of; a) terms of species richness in ungrazed Broadleaves woodlands (option 1A) in plots that had entered Tir Gofal before 2006 and b) for the grass:forb ratio (a negative indicator) for upland heath (Figure 15)

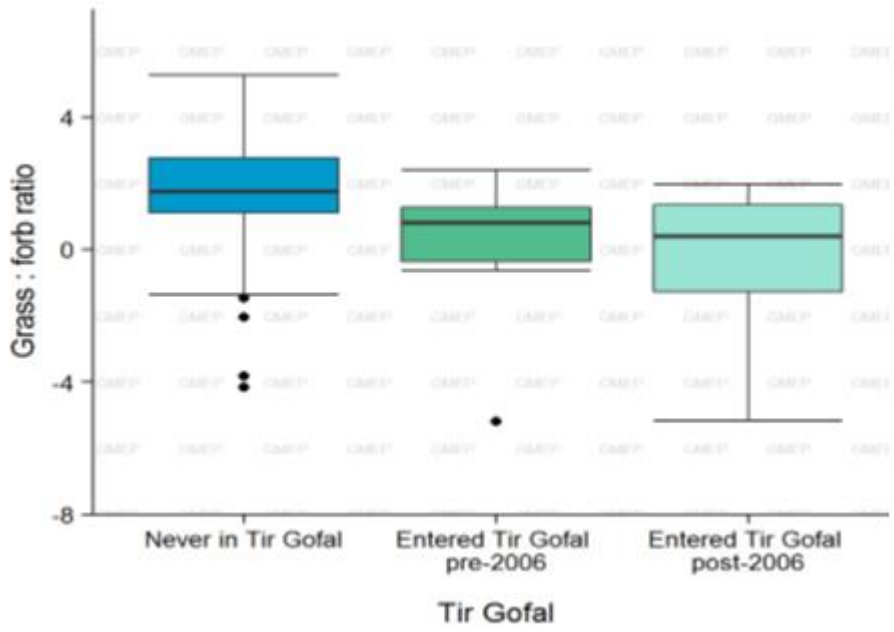


Figure 15 *Significant reduction in the grass:forb ratio in upland heath in land that entered Tir Gofal within the current GMEP sample.*

- We have produced a finely resolved predictive map of Annual Net Primary Productivity for Wales – this essentially is the amount of plant growth and thus underpins agriculture and forestry productivity. The methods uses combination of remotely sensed data and plant trait modelling. Primary Production is a fundamental measurement of ecosystem function and further work will progress the validation of our initial model and explore further relationships with ecological attributes and natural capital across Wales and within survey squares.

The overall picture for biodiversity is some evidence of recent stability for some elements of biodiversity but little evidence currently of improvement. Baseline differences in biodiversity of land coming into the Glastir scheme have been identified which will need to be included in future analyses to avoid false positive impacts being attributed to Glastir.

Climate change mitigation

Agriculture continues to be a significant source of diffuse water pollution and greenhouse gas emissions in Wales; whilst some agricultural practices are also responsible for losses and gains of soil carbon. The Welsh Government has set national targets to improve water quality and reduce greenhouse gas emissions, and the agricultural sector is expected to contribute to the meeting of these targets. In consequence, the Glastir scheme has been developed with sufficient flexibility to target priority themes (such as soil carbon) in a spatial context, and introduce measures on farms to e.g. enhance carbon sequestration, reduce greenhouse gas emissions and diffuse water pollution from the agricultural sector. The Welsh Government has prioritised funding for options focussed on climate change mitigation and diffuse water pollution for Years 1 and 2 of the scheme.

As a first step to determine the potential impacts of Glastir on greenhouse gas and diffuse pollution emissions and carbon sequestration, the Welsh Government tasked the Glastir Monitoring and Evaluation Programme to assess the potential impact of Glastir options on these priority areas through modelling (including emission source not included in the greenhouse gas inventories), work to identify the wider benefits of the Glastir Efficiency Grants and a scoping study to identify barriers for uptake of the Woodland Creation Scheme. Woodland creation is one of the few mitigation activities which can directly capture carbon. Most other measures are only able to reduce emissions. The Year 1 GMEP Report provided an initial description of the modelling ensemble approach we used. In Year 2 we have continued to monitor ongoing national trends of greenhouse gas emissions but enhance these to include embedded and indirect emissions and applied a process model to explore potential changes due to climate change which will be superimposed on the long term outcomes of Glastir.

Highlights from Year 2

Greenhouse gas emission trends from the national inventories

- In 2012, Agriculture contributed 13% of CO_2e emissions in Wales, with methane (CH_4) and nitrous oxide (N_2O) representing 64% and 79% of total Welsh emissions of these two gases, respectively (Figure 17). In total, 6,142 CO_2e were emitted by agriculture in Wales in 2012; comprising 47% as CH_4 (2,864 kt CO_2e), 44% as N_2O (2,707 kt CO_2e), and the remainder associated with transport.
- Enteric fermentation contributed >80% of total agricultural CH_4 in Wales (2,294 kt CO_2e), manure management representing the remaining CH_4 emission. Dairy and beef cattle were responsible for 63%, and sheep 34% of agricultural CH_4 emissions.
- Agriculture is the dominant source of N_2O in Wales, with >90% (2,491 ktCO_2e) of this arising from agricultural soils. The key sources of N_2O from agricultural soils are: fertiliser nitrogen, grazing returns and manure applications.
- Agricultural sector GHG emissions in Wales have decreased by >20% since 1990 (Figure 17). There was a small increase of less than 1% in emissions from 2011 to 2012 mainly due to a 1% reduction in cattle numbers balanced by an increase of 3% in sheep numbers. The overall trend in reductions of (N_2O) emissions from soil have been the result of reductions in fertiliser nitrogen use (particularly in grasslands) and reduced numbers of livestock (manures and urine deposition) over the past decade. Current (2012) annual emissions of N_2O for Wales are 2707 kt CO_2e (8.73 kt N_2O). The trend in the reduction of livestock numbers has also resulted in lower CH_4 emissions. The stabilisation of numbers in recent years means that there has been little change in emissions between 2011 and 2012 (0.2% increase).

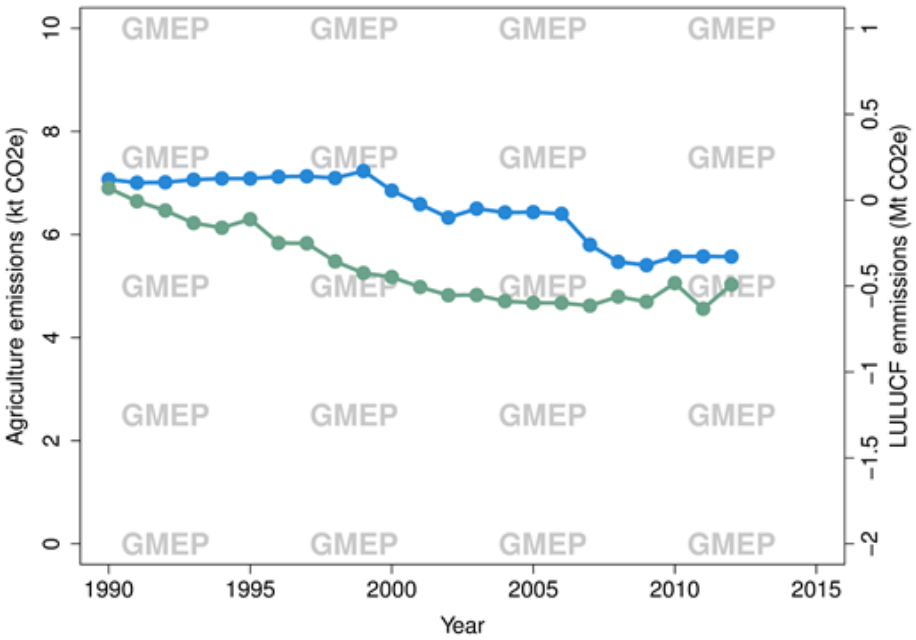


Figure 17 *Greenhouse gas emissions from agriculture and land use, land use change and forestry (LULUCF). Note the differences in scale; 0-10 for agriculture and -2 to 1 for LULUCF. Negative numbers indicate an uptake of carbon. LULUCF activities are clearly not compensating for emissions from agriculture.*

- Wales is a small net sink of greenhouse gases from LULUCF activities (Figure 17). Between 1990 and 2012, the carbon sink in Welsh grassland increased slightly (emissions have become more negative), while emissions from cropland have decreased. These trends reflect conversion of cropland to grassland dating back several decades, as it takes many years for the amount of carbon stored in soils to stabilise after conversion between one land use and another.

Carbon Footprinting including indirect and embedded emissions

- On this set of 16 Welsh model farms, the 4 Glastir options explored is projected to have had the intended effect of reducing GHG emissions and (in most cases) increasing C-sequestration in biomass and soils.
- The effectiveness of the different options in reducing GHG and increasing C sequestration varied between farm types.
- The tool indicated the GHG reductions were mediated primarily through reductions in livestock, with small additional reductions associated with lower requirements for farm inputs associated with stock management. These reductions to inputs extend the impact of the scheme option beyond the boundaries of the participating farm, and into the upstream agricultural supply chain.
- Reductions in livestock numbers may or may not lead to reductions in farm productivity and hence the economic and supply performance of the farm, although this is difficult to predict with confidence.
- The tool indicated the conversion of grassland to woodland resulted in a net increase in carbon sequestration but the effectiveness of the “woodland margin extension” and “streamside corridor” options is limited by the small number of farms with applicable land.

Potential Effects of Glastir Efficiency Scheme Grants on Farm Carbon Footprints

- Insufficient time had passed for farmers to implement GEGs grants on their farms to assess their effect on carbon footprints. Instead, this initial survey was used to establish a baseline year from which to compare carbon footprints after GEGs grants have been completed,

- The average estimated footprint per hectare across all farms was 10,236.0 kg CO_2/ha/yr, and ranged from 2,385.1 kg CO_2/ha/yr to 18,987.2 kg CO_2e/ha/yr.
- The average footprint per hectare on dairy farms (14,032.9 kg CO_2e/ha/yr) was almost double that of LFA cattle and sheep farms (7,704.8 kg CO_2/ha/yr).
- Smaller farms (11,654.3 kg CO_2e/ha/yr) averaged a higher footprint per ha of land than larger farms (7,602.0 kg CO_2/ha/yr).
- Based on this study recommendations include:
    - Carbon footprinting to be repeated on the current sample of farms, at an appropriate point in time after construction and use of GES-funded capital items. This will allow a comparison between baseline emissions and emissions post-implementation, acting as an impact indicator of the scheme.
    - Prioritisation of further grant allocation to the dairy sector, subject to feasibility.
    - Prioritisation of further grant allocation in the SME category.
    - Avoid allocating soil aeration grants to farms where aeration would be conducted on peat soils.
    - Assessment of the impact of GES on ammonia volatilisation, as this is likely to be an important environmental and human health benefit of implementing some SME technologies.
    - The statistical trends in data illustrated in this report should be interpreted with caution, as the number of farms sampled within each category were too small to draw any robust conclusions from.

Effects of Reduced Fertiliser N Use and Climate Change on Spatial GHG Emissions

- The ECOSSE model differs with respect to the models used in the GMEP Year 1 scenario work in that is a process-based model so is capable of quantify changes to GHG emissions in the longer term when emission factors which underpin other models may change e.g. in response to climate change. These models are the ideal but require a great deal of data and there remain uncertainties in the science and the scale of results is significantly reduced compared to the other models.
- ECOSSE estimated mean annual net GHG balance at baseline climate of 0.2 t CO_2e /ha/y, which is equivalent to a net C loss of 54 kg C /ha/y.
- The Glastir measure of reducing N fertilizer to reduce GHG and SOC fluxes could reduce the annual net GHG balance from 0.20 to 0.17 (for a 20% N reduction), and to 0.15 (for a 40% N reduction) t CO_2e /ha/y, respectively.
- The overall conclusion is that the model indicated climate change will not significantly affect net GHG fluxes from Welsh soils or Net Primary Productivity by vegetation by 2050. This is primarily a result of the small differences between the baseline and 2050 climate scenarios (about ±2%).

Overall the picture for the contribution of agriculture and land use to greenhouse gas emissions is one of major improvement from 1990 – 2010 by ca. 20% but with recent cessation of that trend with no recent reduction over the last 5 years. Further improvements are going to be challenging as a result of Glastir considering the aging of the forest stock, limited uptake of the woodland creation scheme and the anticipated limited effect of Glastir on stock numbers.

Soil quality

Healthy soils produce our food, feed and fibre, whilst providing other important functions such as regulating climate and water and attenuating pollutants. They are a biodiverse ecosystem in themselves needing to be fed and watered, and contain an estimated quarter of global biodiversity, whilst remaining relatively unexplored with only ~1% of species as yet identified. It is the diversity of life below our feet that provides the engine fuelling nutrient cycling, breakdown of waste, water filtration and plant growth which is why soils are central to environmental and biodiversity monitoring.

The status and trend of topsoil (0-15cm) change across Wales has been captured by the Countryside Survey since 1978. The last survey in 2007 presented changes for a wide range of physical, chemical and biological properties of soil. Overall, the picture was one of stable or improving topsoil quality with the exception of arable soils. It should be noted the methods used in CS (and other soil monitoring programmes such as the National Soil Inventory) are recognised as being inadequate for peat soil monitoring and thus new approaches have been commissioned within GMEP to tackle this. See Chapter 2.

In Wales, funding from agri-environment schemes (AES) has been available since the early 90s including ESAs, the Habitat Scheme, Woodland Grant scheme, Farm and Conservation grant scheme, Tir Cymen, Tir Cynnal, Tir Gofal and now Glastir. Monitoring of farms under Tir Gofal (Welsh Government, 2013) reported that, 'Soil pH and extractable phosphorus levels were observed to be lower on Tir Gofal farms compared to non- scheme farms. However, this difference may not be due to Tir Gofal management, and was thought instead more likely to be attributable to Tir Gofal management options being applied to areas of more marginal land. Across all the remaining soil quality indicators (bulk density, erosion vulnerability, depth of peat material, organic carbon and carbon to nitrogen ratio) no positive differences were recorded between Tir Gofal and non-scheme farms.' Although the report revealed few positive benefits to soil quality in comparison to farms that had not entered the scheme, this finding could be due to several factors. Firstly, the monitoring timescales (< 3 years) may have been too short to determine significant change, secondly the pair-wise comparison of farms in and out of the scheme may have been the wrong sampling approach (i.e. not enough samples, incorrect pairing), and thirdly there may actually have been no significant benefit from the scheme. As it is impossible to resolve which of these three are valid, it is hoped that the current Glastir monitoring statistical design will help resolve these issues.

The aim of the Glastir monitoring of soil quality is to collect evidence for the effectiveness of bundles of management options in helping to deliver improved soil quality that will address the outcomes of interest related to climate change, biodiversity, soil and water quality and woodland expansion. The compatibility of the current monitoring with Countryside Survey means it can draw on this data record to understand and disentangle changes in national trends from the specific impact of option bundles. The monitoring is also required to collect evidence to quantify the status and trend of water and soil quality in general for other reporting requirements and this work will provide an important counterfactual evidence base. Synthesis and analysis of this data will seek to identify how the Welsh environment is being impacted by drivers of change, such as landuse, climate and pollution over and above Glastir options. Much of the data from the soils work provides evidence for the integrated analysis, and also helps support modelling studies.

When expecting to see the impact of options it is important to consider that based on the findings of the soil quality monitoring performed under Glastir, alongside previous national surveys (e.g. Countryside Survey), it can be expected that major changes in soil quality at the national level will not be revealed in the short-term. For example, 10 years of monitoring are typically required to reveal significant changes in some soil attributes (e.g. carbon status) whilst the dynamics of other

attributes such as biodiversity are unknown. Although the rolling monitoring programme implemented under Glastir has greater statistical power than previous surveys, it is still unlikely that trends in soil carbon will become apparent for at least 5 years or possibly longer, though it has the advantage of linking to the 30 year Countryside Survey data set which provides greater statistical power. Also, it should be remembered, the inclusion of soil attributes is essential in the interpretation of other responses in vegetation, GHG emissions and water quality.

Major achievements in Year 2.

- Main 2014 survey
    - Trained 12 surveyors in soil sampling methods.
    - Surveyors sampled ~450 plots and collected 4 soil samples from each (~1800 samples in total).
    - CEH Labs measured cores from 435 plots to determine 45 parameters for physical, microbial, chemical, carbon and invertebrate analysis. This data supports the outcome analysis in all categories.
    - Implemented new lab protocols to improve efficiency including methods for soil water repellency using video to determine hydraulic function.
    - Analysed all 2013 data and submitted to the GMEP data portal.

- Soil Natural Capital Accounting
    - Proof of concept conducted combining soil and land cover data sets to assess soil resource areas under different Broad Habitats

Main findings

- Topsoil quality for a range of metrics has been characterised for Welsh Broad Habitats (Figure 18)

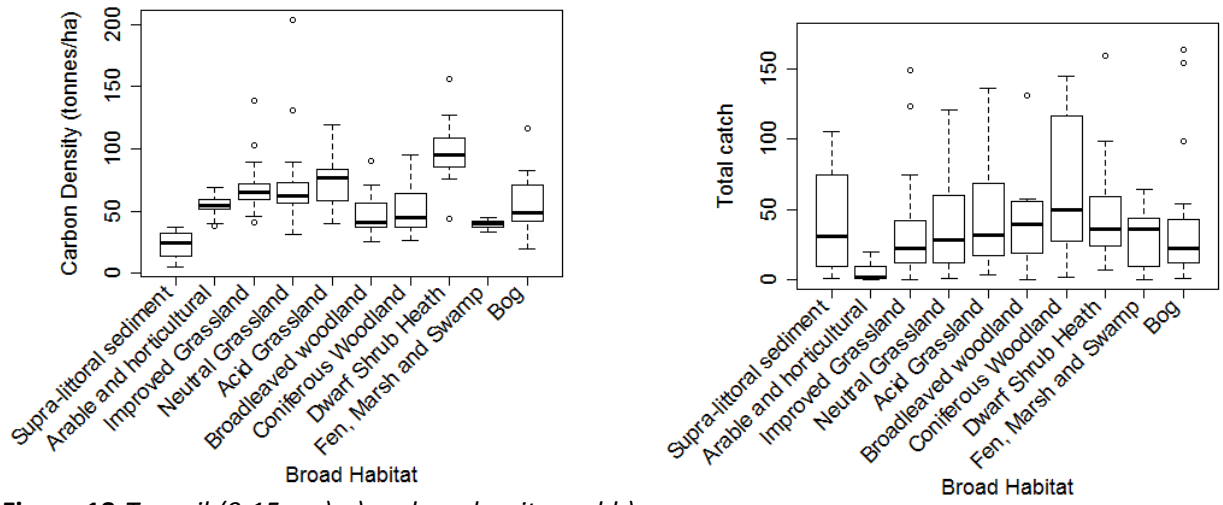


Figure 18 *Topsoil (0-15 cm) a) carbon density and b) soil mesofauna within different Broad Habitats across Wales in 2013. Note total carbon stock to the full depth of the peat profile in bogs is the largest of any habitat. However, the top 15cm of peat whilst carbon rich has a much lower density than mineral soils thus the relatively low values. Top soil (0-15cm) only sampled due to costs involved sampling to depth and it is considered to be the soil horizon most impacted by land management issues.*

- Long term trend analysis has identified no overall change in soil carbon concentration (Figure 19)

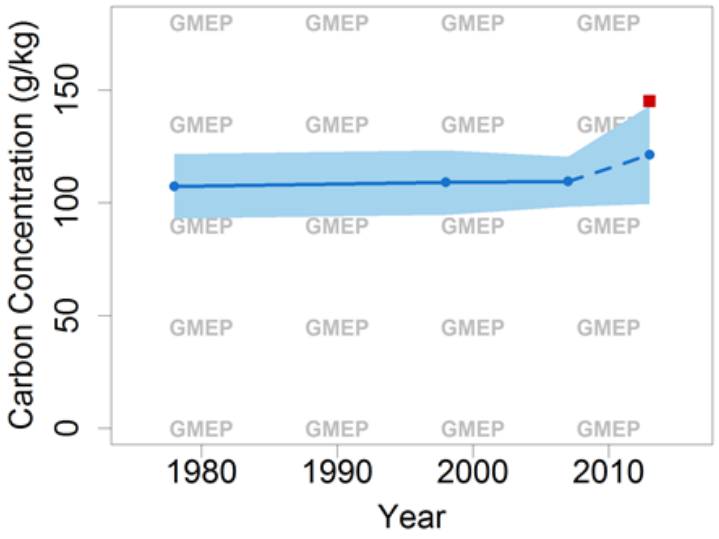


Figure 19 *GMEP data for topsoil carbon concentration for 2013 compared with data collected since 1978 by the Countryside Survey. Solid blue line (CS data); dashed blue line (GMEP 2013 Wider Wales Survey); Red square dot (GMEP Targeted survey)*

- Since 1978 topsoil acidity was reduced probably due to decreased inputs of acidic atmospheric deposition. Nutrient levels since 1998 when records started indicate no change in nitrogen levels and a stabilisation of a recent decline in soil available phosphorus levels (Figure 20). Levels are still acceptable for production but will have reduced the risk of phosphorus leaching to freshwaters. No change in topsoil animal populations were found since 1998.

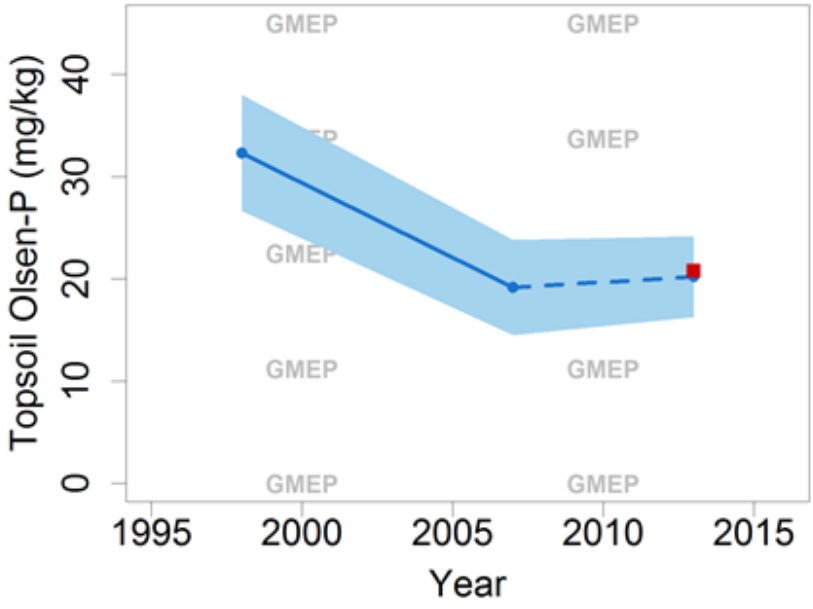


Figure 20 *Long term trends in topsoil phosphorus availability (Olsen-P) using CS data (blue line); dotted line GMEP Wider Wales Survey; and re square (GMEP Targeted survey).*

- Evidence for water and wind erosion is sparse at national scales across the UK including Wales. GMEP does not have the resources to fill this gap however we need to quantify the impacts of Glastir. We are therefore using a modelling approach which provides both

erosion estimates and area of land likely to be at risk of erosion loss and mitigating sediment delivery. See the GMEP year 1 report for more information.

- No evidence of the limited samples in the Year 1 survey of any difference in topsoil quality of land coming into the Glastir scheme. This analysis will be repeated when the full Year 1-4 survey is complete.
- Exploration of the impacts of management using differences under existing land management suggests land management will change soil condition
- Topsoils in Wales are incredibly diverse and appears most responsive to land management regime compared to soil type indicating Glastir has real potential to influence soil quality.
- A number of initiatives are underway to recognise the value that natural resources provide to the economy. In most countries, national accounts of economic activity are recorded, and indicators such as gross domestic product (GDP) are widely used in government and policy to assess economic activity and progress. However, indicators such as GDP measure mainly market based transactions and are not good indicators of welfare; GDP ignores social costs, environmental impacts and income inequality. GDP also does not deduct the direct cost of the depletion of natural resources on national income nor does it take into account the impact that our resource extraction and use of nature has on the continued functioning of the earth system for life support. Using data available to GEMP we present a proof of concept approach for determining the area of soils for accounting. Using the rare and occasional soils previously identified in the HNV work, we cross analysed these with land cover data from 2007. This allows us to identify the percentage of each soil type under a particular Broad Habitat type.

Overall the picture is one of stability in topsoil condition over the last 2 to 3 decades for the metrics we have available. Erosion is the main issue which is not covered by GMEP and for which other data is very sparse.

Freshwater

Headwater streams are an important part of the river network, they typically account for most of river length in catchments (typically 70 to 80 %). The biota of headwater streams makes a significant contribution to biodiversity at a national level with many plants and animals geographically restricted to these characteristic habitats, while some use these habitats seasonally or intermittently. EU legislation aims to protect headwater streams through the Water Framework Directive (WFD), where all water bodies are expected to reach good or high ecological status, the Habitats Directive, and the UK Biodiversity Action Plan where headwater streams are considered ‘priority habitat’ and hence a focus for conservation. Headwaters also harbour species protected under the Wildlife and Countryside Act 1981 and its amendments (e.g. white clawed crayfish), nationally important species of fish such as Atlantic salmon, brook lamprey and bullhead, and can support protected species of mammals and birds (e.g. otters, kingfishers).

Agricultural practices such as livestock grazing and tilling can lead to soil erosion and run-off of fine sediments, nutrients and pesticides into headwater streams. This has direct effects on the biota and habitat integrity, for example decreasing biodiversity and causing a replacement of sensitive fauna by pollution tolerant types. Cumulative impacts across headwaters are reflected further down the river network, decreasing the water quality of larger waterbodies, with negative consequences for their biota, and for ecosystem services such as the provision of clean water for human consumption, fish farming and recreation. Hence it is not surprising that water quality is a key target of many agri-environment schemes, including Glastir, with measures that aim to reduce run off and increase ecological buffering along streams and rivers.

Headwater streams are currently under-represented in NRW monitoring programmes which GMEP is intended to fill. The NRW target ultimately is all surface waters to reach good ecological status as

required by EU legislation. However, the size and vast numbers of headwaters means that it may be a strict WFD approach may not be practical. As headwater streams also need to be reported under the habitats directive as they are 'priority habitats' is may be more appropriate to report impacts results for headwaters under Priority habitats rather than the WFD compliance. GMEP and NRW will collaborate to produce, by the end of the baseline, an ecological status assessment method based on the field survey that is consistent with WFD reporting, but in this report we comment on ecological quality with no translation to consequences under the WFD. Impact of Glastir on larger rivers will be explored using a modelling approach to quantify change in the contribution of agriculture to nutrient inflow in Year 4 however formal WFD assessment will rely on NRW ecological assessments. There is no benefit of GMEP repeating this assessment.

Ponds are more abundant than rivers and lakes, and are found in virtually all environments. Though the diversity of an individual pond will generally be less than that of a river or lake, their biodiversity value lies at wider spatial scales. are a particularly important habitat for some rare and protected species. In Wales, this includes many species which are declining internationally such as yellow centaury and three-lobed crowfoot, as well as European protected species including great crested newt and floating water-plantain. In addition, ponds provide both habitat and food for terrestrial wildlife such as birds, bats, small mammals, reptiles, and pollinating insects, making them important in agricultural and urban landscapes that have few natural refugia. Ponds, are recognised in Article 10 of the EU Habitats Directive for their role as 'stepping stones', between other waterbodies and wetlands, increasing freshwater habitat connectivity at wide spatial scales. Ponds also act as small reservoirs as they collect and slow the flow of water off fields and other areas, trapping and recycling nutrients and sediments before they can enter a flowing water body. Due to their small size, compared to a river or lake, they are particularly sensitive to pollution and have a limited buffering capacity. In agricultural landscapes ponds receive sediments, nutrients and pesticides which has direct effects on the biota and habitat integrity, for example decreasing biodiversity and causing a replacement of sensitive fauna by pollution tolerant types.

Within the GMEP, survey squares are sampled for 1 headwater stream and 1 pond when present. Resources do not allow sampling of more even if present. The techniques deployed in headwater streams are all recognised bio-monitoring approaches. Currently the GMEP assessment is not a WFD assessment though the aim is to establish a framework by the end of the baseline survey. Because it is based on one survey in summer, sampling probably underestimates ecological quality a little compared to spring/autumn, but ecology is not the dominant factor which lowers the quality of a stream rather it is habitat modification and water quality (see below). Improvements in water quality from Glastir may therefore not translate to WFD compliance without active habitat restoration.

In ponds, the techniques most widely used, and recommended by the Freshwater Habitats Trust, were used (there is no recognised standard technique at either the UK or EU level) to monitor macroinvertebrates, macrophytes and habitats. These techniques allow us to determine chemical water quality as well as ecological quality. Due to the time required for identifying the many invertebrate and diatom samples the Year 2 (2014) is not yet ready for reporting.

Main findings:

Headwater streams

- 57% of survey squares had at least one headwater stream
- Lowland sites demonstrated nutrient enrichment vs upland sites
- 85% of sites had phosphorous concentrations consistent with supporting good ecological quality, the remaining sites were all in the lowlands bar one
- 53% of sites had nitrogen concentrations that exceeded the range associated with unimpacted European rivers. No site exceeded the drinking water standard for the UK.

- Lowland sites demonstrated higher levels of habitat modification
- Overall, 91% of headwater sites had modified habitats, with 32% displaying high levels of modification (Figure 21)
- The principal drivers of macroinvertebrate communities were biogeographic (altitude, alkalinity, conductivity) but human habitat modification was also a driving factor
- Diatoms (a major group contribution to primary productivity) were more responsive to the altitude gradient, with better ecological quality in uplands (expected as diatom indicators principally respond to nutrient status) but higher diversity in lowlands, as expected
- Macrophyte indicators showed most sites had intermediate levels of enrichment, only 1 lowland site could be diagnosed with clear eutrophication impacts and 12 sites (9 of which in uplands) could be diagnosed as unlikely to be impacted by eutrophication or organic pollution
- Macroinvertebrate indicators indicated 62% of sites had macroinvertebrate communities consistent with good ecological quality. The principal diatom-based score was less conservative, indicating 91% of sites had diatom communities deemed of good ecological quality.

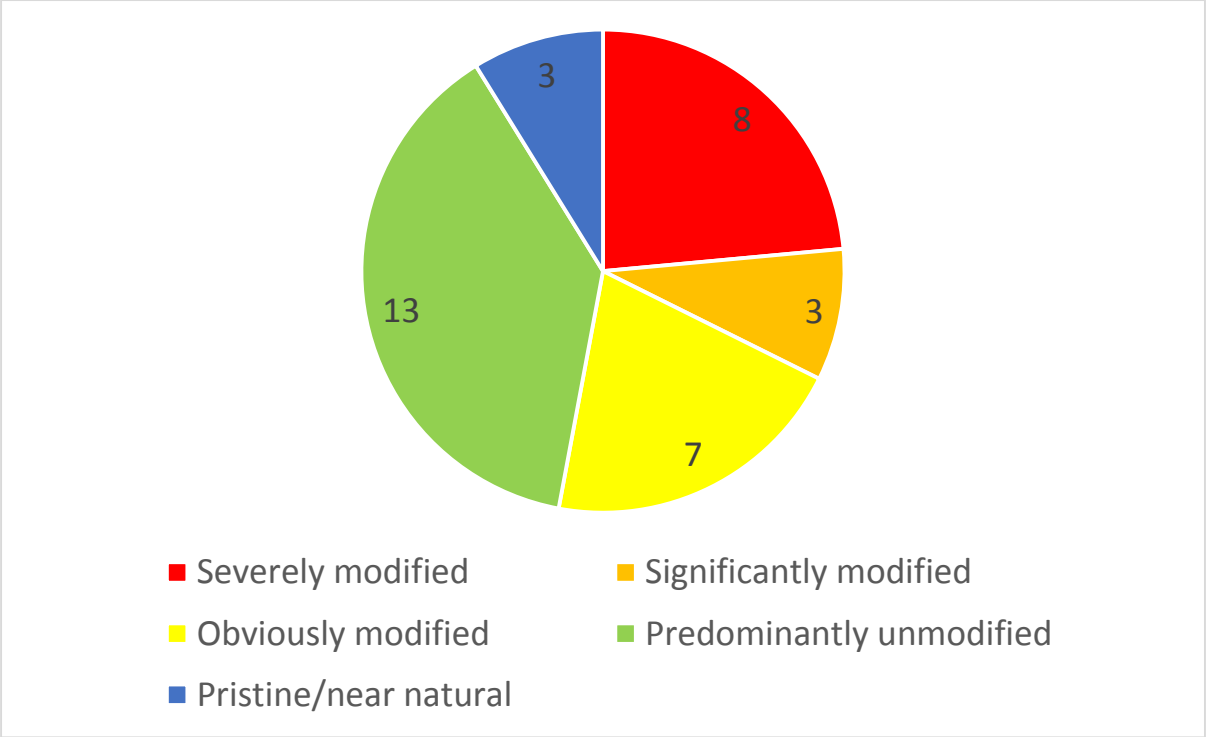


Figure 21*: Number of headwater sites falling in the 5 habitat modification classes in GMEP survey from year 1*

- Long term trends using NRW data where we have screened out larger rivers includes a lot more than headwaters which are limited to 2.5km from source, for which data is sparse but perhaps provides some information on past trends of small rivers in Wales. The data indicates an improvement in ecological quality of smaller streams over the last two decades, linked to improvements in water quality. This is consistent with the UK wide pattern (Figure 22).

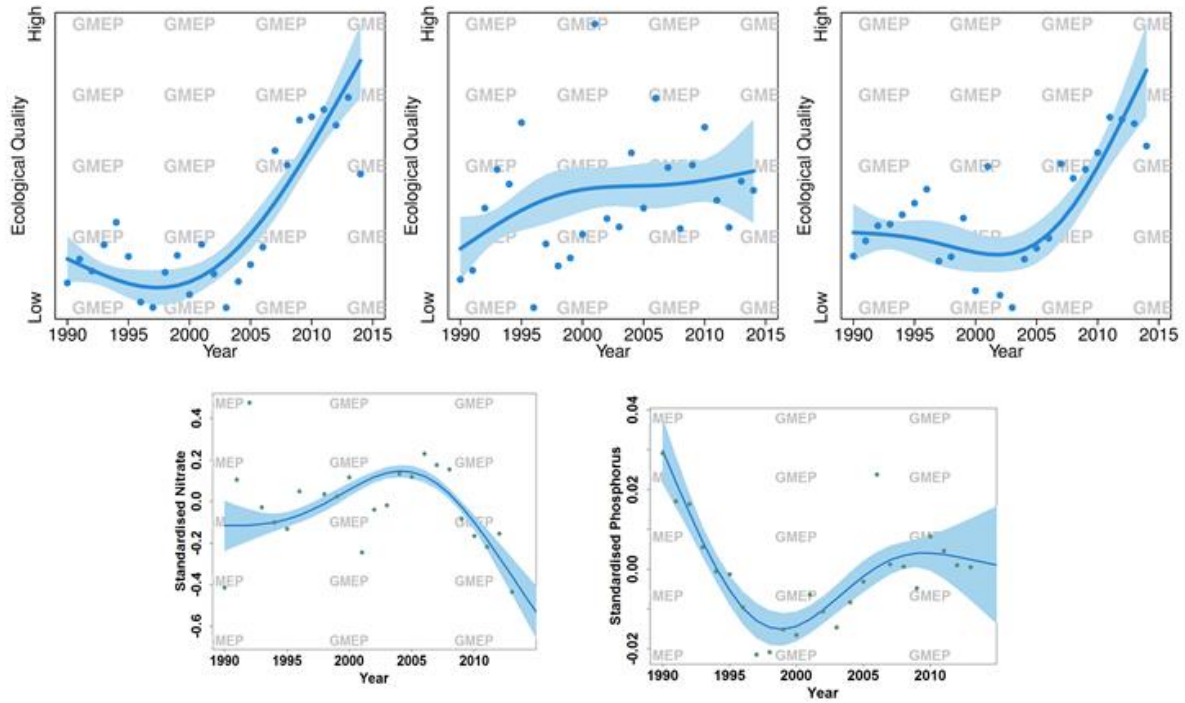


Figure 22 *Top: BMWP score (left; an index of eutrophication and general degradation), Ntaxa (middle; the number of water quality sensitive taxa that contribute to the WHPT score) and ASPT (right; the sensitivity of the taxa to water quality which contribute to the WHPT score). Bottom: Time series of soluble reactive phosphorus (SRP) (mg/L) and right: total dissolved nitrogen (TDN) (ppm) time series derived from NRW monitoring where large rivers have been removed. Note this includes many smaller streams which are not headwater streams but provides some historical context.*

- There was a trend (not significant at present but likely to become so as more baseline samples are taken) of higher quality headwater streams on land within the Glastir scheme which needs to be taken into consideration in future analysis of the benefits of Glastir.
- No significant legacy effect of previous agri-environment schemes was detected though there was a trend for a positive effect on ecological quality and sample size was low as this represents only Year 1 of the full 4 year GMEP sampling period (Table 03). Our power to detect change will increase with the 4 year population.

	Status	Mean	SE
Ntaxa	Outside Past AES	16.44	2.06
	In Past AES	19.19	0.98
ASPT	Outside Past AES	5.66	0.28
	In Past AES	5.83	0.14
BMWP	Outside Past AES	93.44	11.69
	In Past AES	110.12	7.17

Table 03 *Mean values of three main macroinvertebrate indicators of ecological quality in survey sites falling in or out of previous agri-environment schemes.*

- An appropriate target for Glastir would be to increase the number of 'good' quality sites under the WFD (hence a target for GMEP is to produce a WFD- compliant assessment that can be used to report the number of sites according to WFD statsus classes (high, good, moderate, poor, bad)Whilst experience indicates if nutrient inputs at source are controlled a rapid change in instream nutrient concentrations can be achieved, the biological community needs to respond to that change before there is a change in status. Thus recovery of these

systems may not be achieved by removing the stressor alone if the source pool of recolonizing of desirable species is so depleted that the biology cannot respond (a similar issue to the identified in GMEP year 1 report for plant species recovery). This issue is well known across the EU. Therefore CEH's recommendation is an adaptive management framework which can revise its strategy as more info becomes available and also allows flexibility on the main focus i.e. should Wales prioritise more good sites, less bad sites, or both?

Ponds

- 48% of survey squares had at least one pond
- There was a trend for nutrient enrichment in lowlands which was not significant
- Macrophyte indicators reflected the nutrient conditions as expected, though more uncommon species were found in uplands
- The main drivers of the macroinvertebrate community were natural (alkalinity, altitude) but phosphorous concentrations were also an important driver and are likely to be influenced by human activity
- Only 8% of ponds were judged to be in good ecological quality, most others fell under moderate quality(Figure 23) (Note that ponds are not monitored under the WFD so the terms good and moderate do not relate to WFD terminology)
- As for streams, no significant difference between pond quality in and out of scheme was detected but there was a trend for a positive effect of Glastir on ecological quality which will need to be taken into consideration when the impact of Glastir is assessed. Further survey data will clarify this.

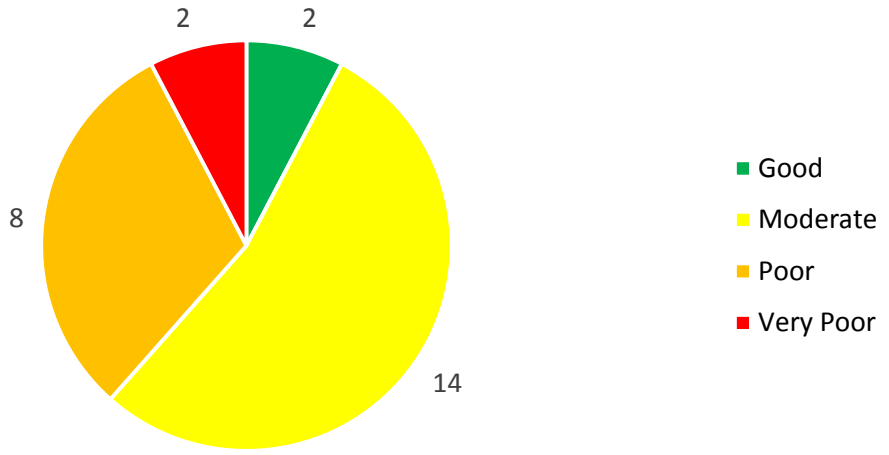


Figure 23 *Ecological quality of ponds in GMEP survey from Year 1 data*

Overall the picture for headwaters is one of recent significant improvement over the last 20 years. Phosphorus concentrations indicate 89% are consistent with good ecological status with similar values for diatoms at 91% indicating good ecological quality. However, macroinvertebrate communities indicate only 62% are consistent with good ecological quality and intermediate levels of enrichment are also indicated by macrophyte communities. 91% of sites remain modified in some way with 32% of sites displaying high levels of modification. For ponds, only 8% were judged to be of good ecological quality, most others were of moderate ecological quality. No evidence of differences to date have been observed for headwaters or ponds coming into Glastir compared to that outside of the scheme. It should be noted, impacts of Glastir on nutrient enrichment levels in freshwaters more generally will be quantified using a modelling work as described in the GMEP Year 1 report.

High Nature Value Farmland (HNV)

HNV farmland has been defined as 'areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports or is associated with either a high species and habitat diversity or the presence of species of European concern or both'. It is an agreed indicator of one of the six Strategic Objectives of Glastir but requires development work to gain consensus as a valid metric which can be reported to the EU.

Previous work carried out at the European scale and within Wales looked at the concept of High Nature Value farmland and how it might be defined and applied. Low intensity agricultural practices may be important in maintaining these areas of high diversity or they may exist despite the farming activities. Spatial heterogeneity is important with habitat mosaics and different structural elements e.g. scrub and linear features. Land which is of 'High Nature Value' is not easily defined, it may be a subjective and contentious exercise choosing which elements best represent 'high value'. It has been generally agreed that HNV farmland can be broken down into 3 types:
Type 1: Farmland with a high proportion of semi-natural vegetation
Type 2: Farmland with a mosaic of habitats and/or land uses
Type 3: Farmland supporting rare species or a high proportion of European or world populations
Within the EU, Member States are committed to identifying and maintaining HNV farming; however, there are no specific rules or generic metrics and criteria established at EU level to determine HNV farmland. Each member state therefore interprets the concept and decides how best to apply it to their state. It is inevitable that there will be variation in HNV farmland definitions, individual countries will have different indicators (particularly for Type 3 indicator species) or landscape features, however, there is also a need for a more integrated approach across European countries with common standards and definitions.

The GMEP team have been tasked by WG to explore these concepts and propose new ideas, criteria and metrics that might be applied to define land of 'High Nature Value' and form an indicator to create a baseline extent and measure changes in extent and quality. We are conducting this work in consultation with a range of partners and stakeholders who are also interested in the potential value of this metric. Specifically this has included a small working group involving CEH, BTO, RSPB and WG who first met in April 2013; a RSPB workshop with a wide range of participants from across the farming and conservation section in May 2013; a GMEP Advisory Group in June 2013 with representative from the farming community, WG, NRW and NGOs and a number of subsequent working group meetings in 2013/2014. A wide range of views were expressed which range from this "is a metric of little value which could confuse rather than illuminate" to "a potentially useful metric to communicate overall trends in biodiversity".

Major Achievements in Years 1 and 2

- Convened and met with a range of stakeholders to discuss possible approaches and agree a way forward
- Collated a table of possible metrics for HNV
- Collation of potential datasets from which to calculate metrics
- Development and calculation of metrics e.g. connectivity, habitat diversity, rare species, rare soils etc. (Figures 24 & 25)
- Analysis and discussion of the potential to downscale from coarse resolution recording datasets- dataset for plant species produced
- Metrics calculated for four case study areas with proposals presented for next steps (Figure 26)
- We present several methods of potentially assessing the contribution of soil to High Nature Value land.

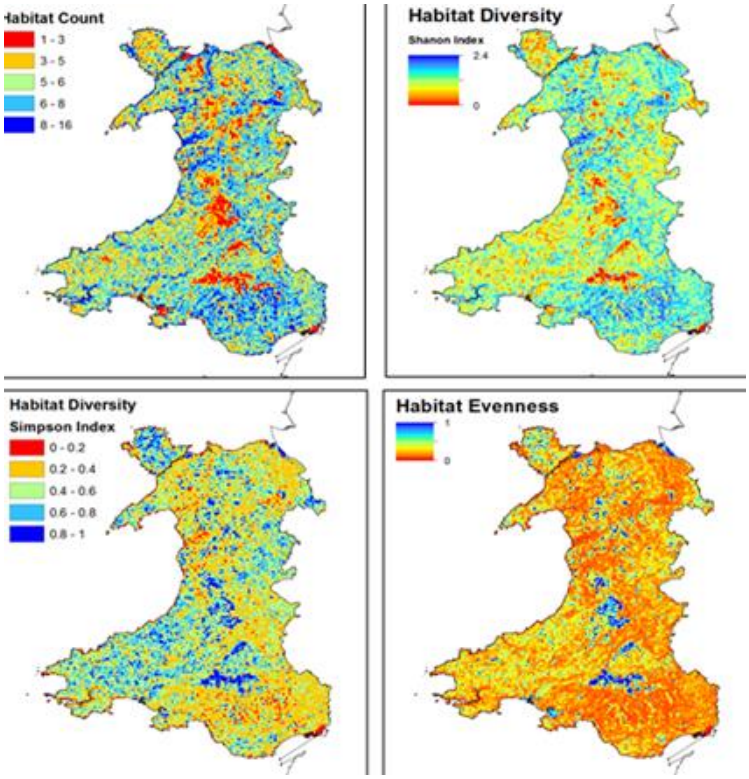


Figure 24 *a) Different approaches to assess habitat diversity for each 1km^2 across Wales based on LCM2007;*

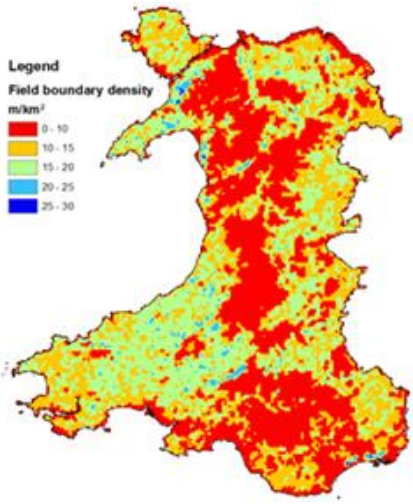


Figure 24 *b) A map of field boundary density across Wales, based on data for the Land Parcel Information System (LPIS)*

Figure 25 *Example maps of species richness within each 10km x 10km grid cell across Wales for different groups of species, based on BRC data.*

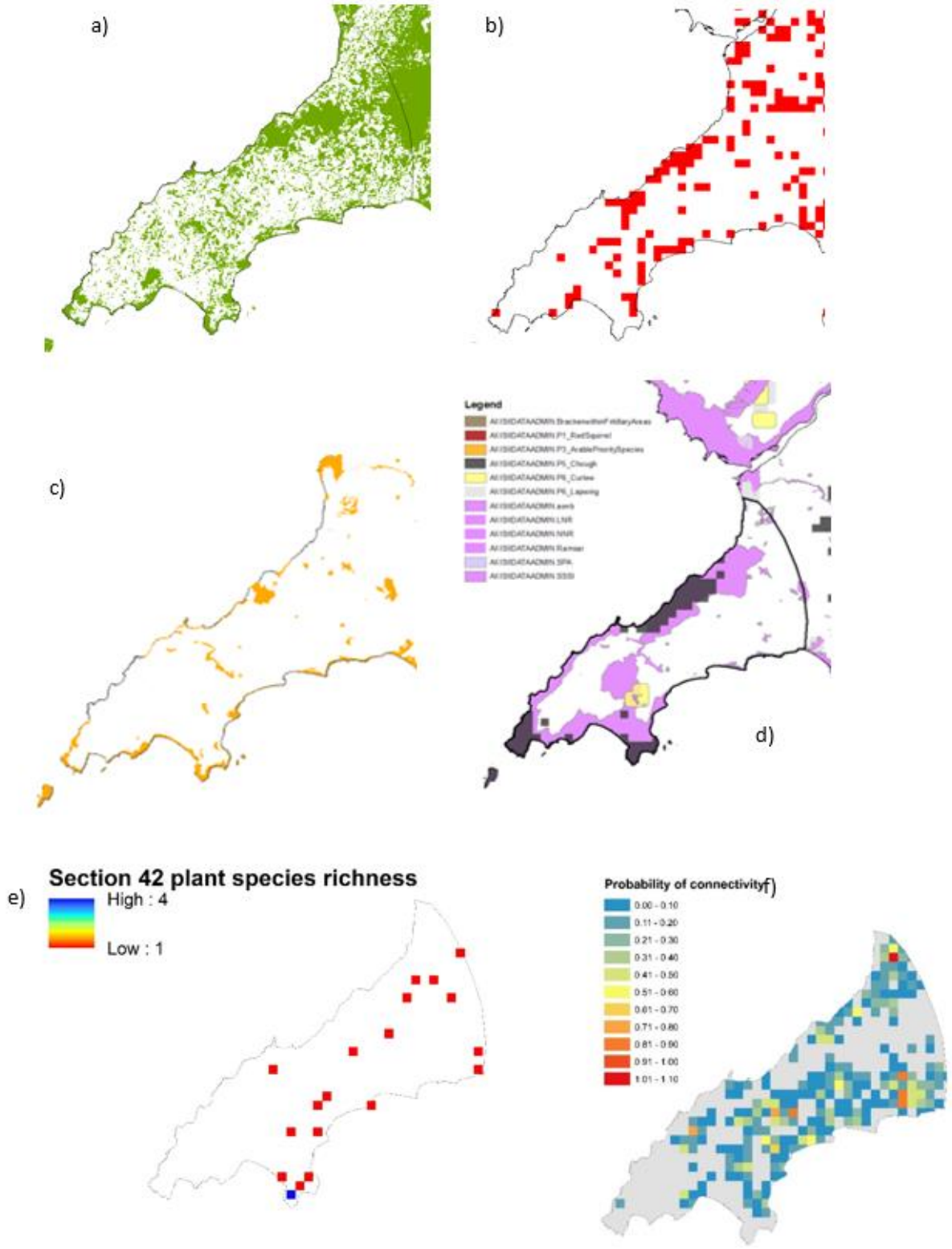


Figure 25. *Maps of potential HNV indicators for Llyn Peninsula, including; a) Type 1 semi-natural habitat patches; b) Type 2 – Upper quartile of habitat diversity (Shannon Index; species data not yet incorporated); c) Type 3 - SPAs, SACs and SSSIs (species data not yet included); d) a map showing*

protected areas and protected zones; e) a map showing the distribution of rare plant species ((section 42); f) and Broadleaf woodland habitat connectivity metrics for each 1 km grid cell
Based on the work undertaken so far the following metrics are being explored for HNV farmland in Year 3:

Type 1 Farmland with a high proportion of semi-natural vegetation:

- Areas of all semi-natural land parcels
- % semi-natural habitat and define a threshold – e.g. > 20 % - for HNV farmland

Type 2 Farmland with a mosaic of habitats and/or land uses:

- Use upper quartile of habitat diversity (Shannon's Index)
- Incorporate woodland connectivity and / or field boundaries into the metric
- Incorporate species richness or presence/abundance of selected species, particularly species which are characteristic of a mosaic of habitats including low intensity farmland

Type 3 Farmland supporting rare species or a high proportion of European or world populations:

- Incorporate data on protected areas SPAs, SACs, SSSIs or use as a separate dataset to compare HNV metric to.
- Adopt Glastir target layers and protected zones to identify HNV areas or use as a dataset for comparison with an HNV metric
- Develop an indicator based on species data, particularly species which are rare or species for which a high proportion of European or world populations are found in the UK.

We present several methods of potentially assessing the contribution of soil to High Nature Value land should the working group decide it is a natural resource which should be included in the HNV metric. We report that even common Welsh soils are relatively unusual in the global context, especially the surface-water-gley soils and to a lesser extent the podzols. We found that all of the rare or occasional soils are covered by SSSI's bar 1 emphasising the close link between soil and ecological properties.
Next steps will include a real-time participatory approach by the GMEP Advisory Group comparing outcomes from different combination of metrics using a web based data mapping tool CEH is developing which will be available in January 2016. Outcomes of different data combinations will be compared to protected areas, Glastir target layers and other metrics of natural capital and ecosystem services to assess their relationship.

Ecosystem Service Trade-off and Opportunity Mapping

Underlying ecological and environmental constraints for ecosystem services have resulted in their current complex spatial distribution in the Welsh landscape. Some services often co-exist as they require similar environmental conditions e.g. carbon storage and water regulation whilst other services are often negatively associated (agriculture production and water quality). The GMEP Year 1 report reported on an initial analysis of the data which highlighted how the GMEP data could be used to quantify these trade-offs and co-benefits. Agricultural productivity and carbon storage were identified to be positioned at different extremes of a gradient from high to low land intensification with biodiversity often at its most species rich at intermediate levels (Emmett et al. 2014). In the future GMEP data will be used to explore these relationships at different scales and for different regions but there is a need now to provide a tool which can help policy makers and land managers target specific areas in the Welsh landscape where opportunities are greatest to increase ecosystem service provision with minimal trade-offs. We have exploited the LUCI modelling tool described in the GMEP Year 1 report to start this process (Emmett et al. 2014). This was the first ever deployment of an ecosystem service model with such fine spatial resolution appropriate for the relatively fine scale options within Glastir at a national scale for 7 services. In Year 2, we have again used the LUCI model to identify where there is an opportunity to improve each service and where these opportunities may conflict. It should be noted that the LUCI model takes into account not just the area modified but the area affected downslope by land management as it has a topographical

routing approach to water flow and nutrient/sediment transport i.e. it is not a suite of GIS maps overlays. Finally it must be emphasised, LUCI provides a useful initial screening tool to identify areas to target for a ground-based assessment and provide national based metrics. It is strongly recommended that areas identified as having high potential for service improvement be re-visited with the model (or another ecosystem service modelling tool) to iterate options with local stakeholders incorporating best available local data. LUCI has been used and indeed was initially developed for this type of local engagement and negotiation approach to development of spatially explicit community planning.

Achievements and key findings

Ecosystem services condition, opportunities to improve, and trade-offs or co-benefits between 7 services were identified using the LUCI model. Calculations have been made on the spatial data to identify for each ecosystem service the total area with good provision, total area with opportunity to improve, and area with opportunity to improve without risk to existing services in good condition. Further calculations were then performed for each ecosystem service to identify where opportunities to improve ecosystem services coincide spatially with good existing condition for each other ecosystem service. Finally, calculations were performed for each ecosystem service pair to identify where both have opportunities to improve. The findings include:

Opportunities to improve services:

- Significant areas have opportunity to improve carbon (C) status (10508km^2), however for the vast majority of these sites, there are other services in good condition, so care must be taken to avoid detrimental effects if options are targeted at improving C status. Many of these trade-offs are with priority habitats (7488 km^2) (largely heather dominated grasslands), agricultural utilisation (5424 km^2) areas reducing erosion risk (9693 km^2), and potential nitrogen (N) (7731 km^2) and phosphorus (P) (9834 km^2) loss to freshwaters . It is likely that changes to improve C status would not increase erosion risk, or potential N and P loss to freshwaters, however the need to protect priority habitats, and socioeconomic value of agricultural production may reduce potential to achieve carbon status improvements.
- Potential N loss to freshwaters has reasonable opportunities (104 km^2) to improve (reduce) without risk of damaging other ecosystem services (ES) or agricultural productivity. Significant proportions of the 5231 km^2 of sites with opportunity to improve (reduce) potential N loss to freshwaters also have opportunities to improve (reduce) potential P loss to freshwaters (1228 km^2), C status (2777 km^2), Broadleaved woodland habitat connectivity (1038 km^2) and mitigation of overland flow which may contribute to flood mitigation (3955 km^2).
- Over 321km^2 were classified as non-mitigated land in terms of runoff, and had no other ecosystem services in good condition, which may indicate significant potential for interventions to reduce flood risk, without damaging other ES or agricultural productivity. However, additional data to improve representation of soil drainage is being explored, and depending on flow regimes not all non-mitigated features currently create flood risk, hence further assessment of these opportunities is necessary.
- Locations with low agricultural productivity that are not in good condition for other ES were mapped as over 97 km^2. Whilst there may be potential to increase agricultural productivity in these locations, land may be less suitable for agriculture, and interventions to improve other ES may be more appropriate.

Calculations have been performed on all outputs to identify where there are trade-offs and win-wins across all 7 ecosystem services considered. Looking at co-location of opportunities to improve ecosystem services for all 7 services indicates that ca. 15% has existing multiple service provision whilst almost 28% of Wales has at least 2 more opportunities to improve services than services to be preserved.

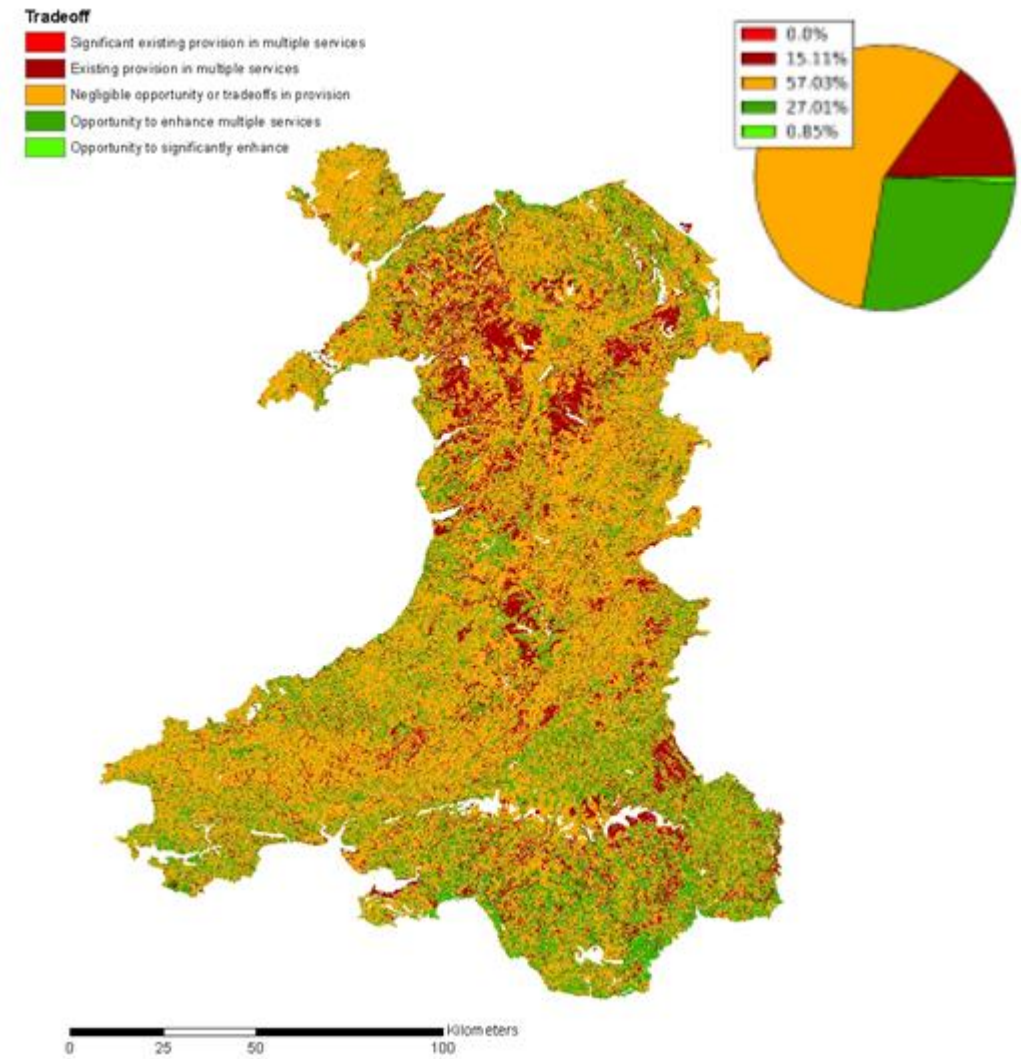


Figure 26 *Outcomes for trade-offs between agricultural utilisation status, carbon status, nitrogen and phosphorus status, erosion status, Broadleaved woodland connectivity and flood mitigation ecosystem services; almost 28% of Wales has at least 2 more opportunities to improve services than services to be preserved.*

An assessment of the amount of land inside and outside of the scheme which was either mitigating or mitigated for rainfall runoff / flood mitigation was calculated. The results suggests there is little difference between the land inside and outside of the Glastir scheme with respect to either mitigating or mitigated features. The values are 19% and 21% for land in and out of scheme for mitigating features and 19% and 17% for mitigated features respectively. Further assessments to assess differences between land coming into the scheme will be undertaken in Year 3. These values provide a conservative estimate, and values are expected to increase slightly with Inclusion of the HOST dataset to account for mitigation from well drained soils.

Ordination of spatial variation environmental constraints indicated that only 3% of spatial variation in combined ecosystem service status can be explained by precipitation, temperature regime, elevation, slope and soil drainage and acidity. This indicates the importance of simulation of topology and topography when assessing condition of the relevant ecosystem services as the service delivery is not directly related to the conditions at the location; for this reason spatially explicit modelling as applied in LUCI has significant benefits over simplified point combination of spatial data.

Testing of LUCI outputs has continued and suggests findings are robust for water flow, agriculture potential and current agriculture utilisation and nitrate export to rivers. As LUCI does not include point sources of phosphorus such as sewage works, further work is required to include these or mask them out from LUCI assessments for future phosphorus assessments. There is a lack of sediment data for testing but the LUCI model also probably needs refining for this service to include land management such as tillage. Current assessment only include the inherent structure of the landscape such as slope and water flow.
Other developments includes significant progress on deploying a web-mapping service for LUCI appropriate for Welsh catchments, and setting up for more temporal /event reporting from LUCI over Wales. New funding has just been won from NERC to make transparent the level of evidence behind the different outputs from LUCI which will be linked to the web-mapping service.

Further information

The complete Year 2 GMEP report outlines in more detail all the work described in summary above with a fuller summary provided in the 'GMEP Report Summary' and a more easily accessible and shorter summary in the 'GMEP Citizen Summary'. The GMEP Year 1 report and many other GMEP findings can be found on the recently launched GMEP data portal https://gmep.wales.